MASSACHUSETTS INSTITUTE OF TECHNOLOGY

APOLLO

GUIDANCE, NAVIGATION AND CONTROL

Submitted by: M H Hamilton Date: 12-30-69
M. H. HAMILTON, DIRECTOR, MISSION PROGRAM DEVEL
APOLLO GUIDANCE AND NAVIGATION PROGRAM

Approved: R. A. Larson Date: 12 30 69
R. A. LARSON, LUMINARY PROJECT MANAGER
APOLLO GUIDANCE AND NAVIGATION PROGRAM

Approved: R. H. Battin Date: 12/31/69
R. H. BATTIN, DIRECTOR, MISSION DEVELOPMENT
APOLLO GUIDANCE AND NAVIGATION PROGRAM

Approved: D. G. Hoag Date: 2 Jan 70
D. G. HOAG, DIRECTOR
APOLLO GUIDANCE AND NAVIGATION PROGRAM

Approved: D G Hoag for Date: 2 Jan 70
R. R. RAGAN, DEPUTY DIRECTOR
INSTRUMENTATION LABORATORY

E-2471

APOLLO GUIDANCE AND NAVIGATION
FLOW CHARTS

PROGRAM LUMINARY 1C

JANUARY 1970

MIT INSTRUMENTATION LABORATORY
CAMBRIDGE 39, MASSACHUSETTS

12.0 THRUST PROGRAMS

P40 DPS THRUST

MAJOR SUBROUTINES AND EXTERNAL ENTRY POINTS

THE ENCLOSED REPLACEMENT SHEETS WILL UPDATE THE LUMINARY 69 FLOWCHART FC-3800, REV. 0, TO LUMINARY IA (LUMINARY 99) FLOWCHART FC-3800, REV. 1.

THE EFFECTIVE SHEETS FOR LUMINARY IA FC-3800, REV. 1 ARE:

SH. 1	REV. 0
SH. 2	REV. 1
SH. 3-4	REV. 0
SH. 5-6	REV. 1
SH. 7	REV. 0
SH. 8	REV. 1
SH. 9	REV. 0

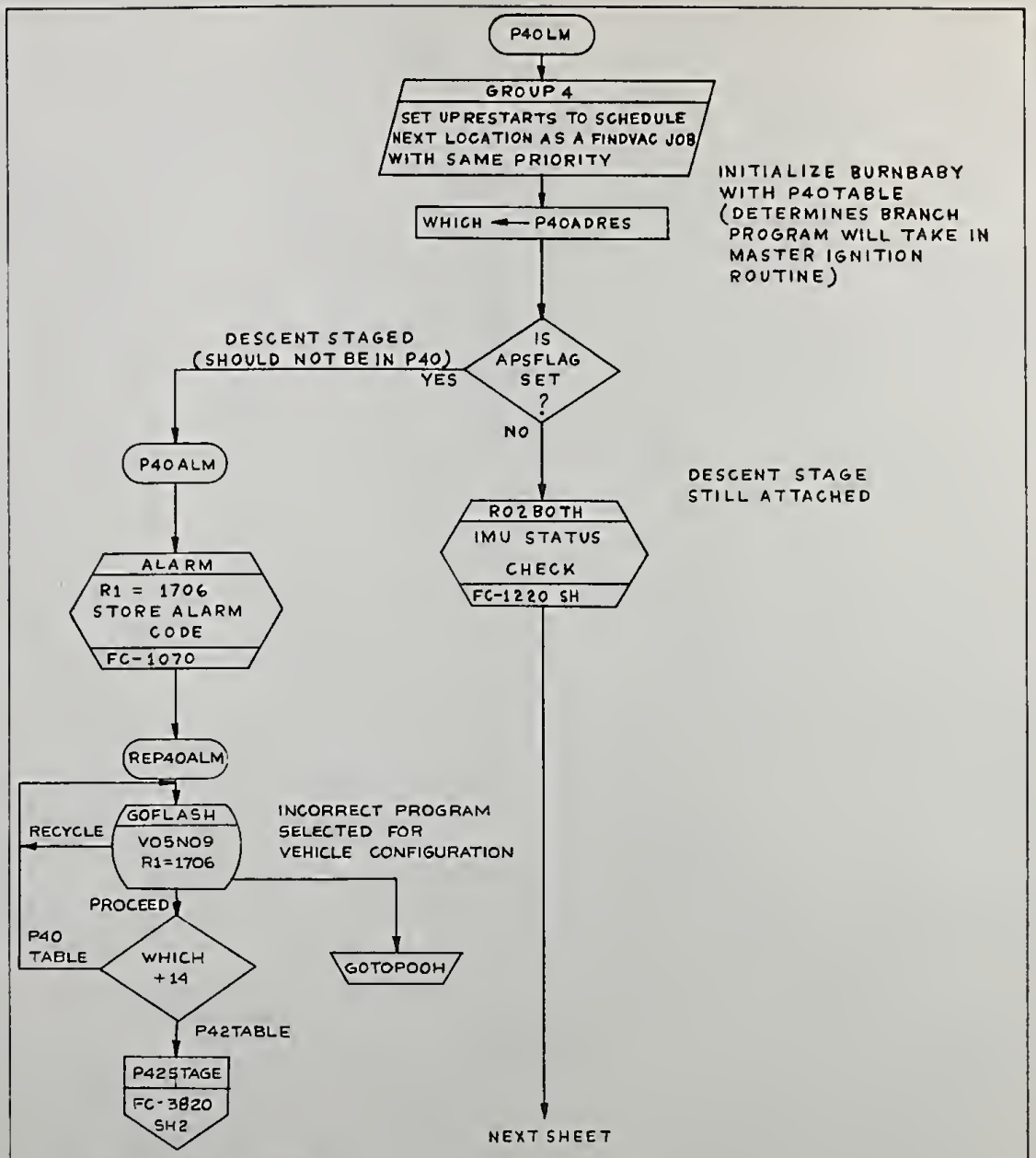
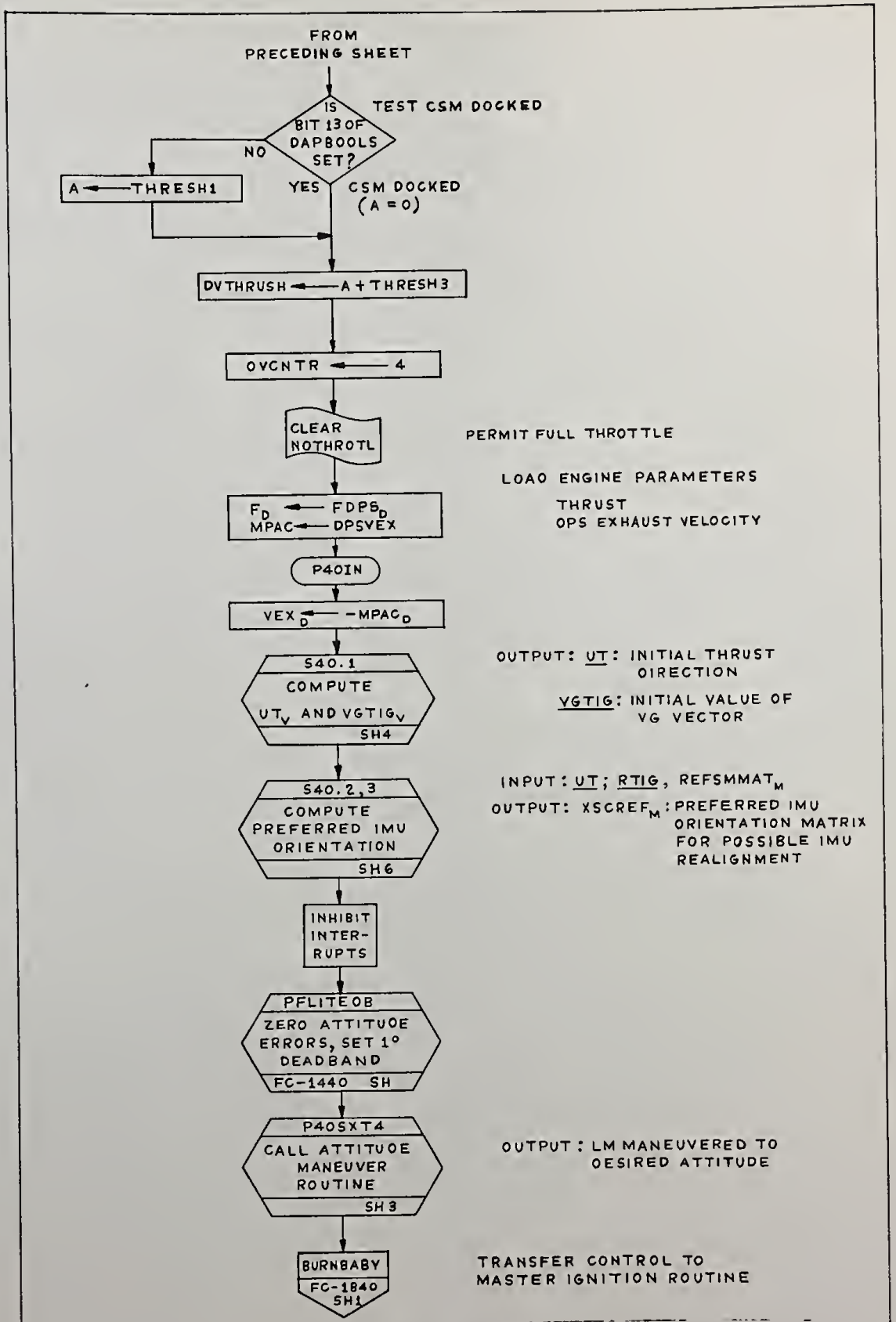
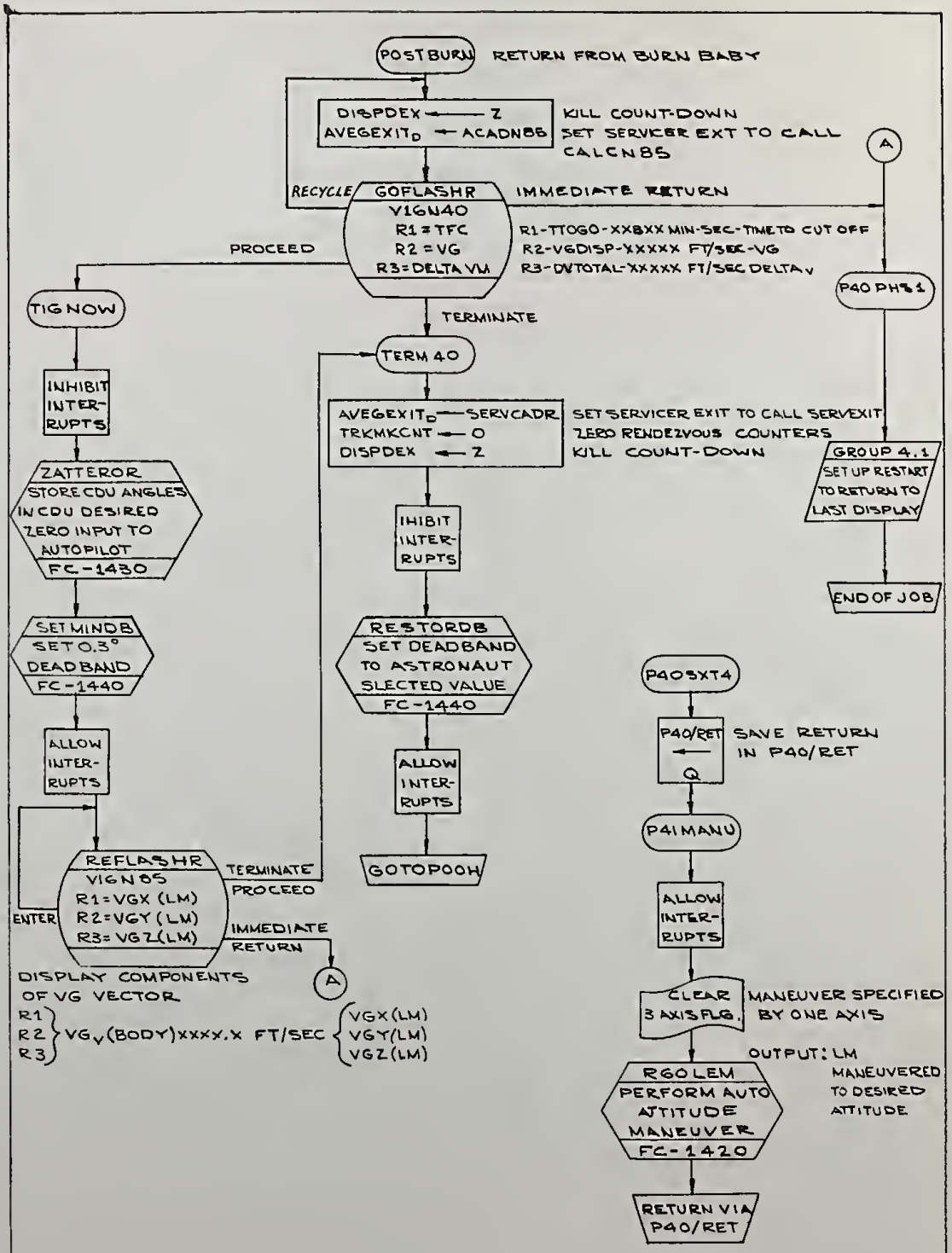


TABLE USED BY MASTER IGNITION ROUTINE — WHICH INDEX

P40TABLE	VN	0640	(0)
	TCF	ULLGNOT	(1)
	TCF	COMFAIL4	(2)
	TCF	GOPOST	(3)
	TCF	TASKOVER	(4)
	TCF	P40SPOT	(5)
	DEC	2240	(6)
	2CADR	STEERING	(7)
	TCF	P40JUNK	(11)
	TCF	WAITABIT	(12)
	TCF	P40IGN	(13)
	TCF	REP40ALM	(14)


FROM PRECEDING SHEET
IS BIT 13 OF DAPBOOLS SET?
TEST CSM DOCKED
NO
YES
CSM DOCKED (A = 0)
A ← THRESH1
DVTHRUSH ← A + THRESH3
OVCNTR ← 4
CLEAR NOTHROTL
PERMIT FULL THROTTLE
LOAD ENGINE PARAMETERS
THRUST
OPS EXHAUST VELOCITY
F_D ← FDPS$_D$
MPAC ← DPSVEX
P40IN
VEX_D ← −MPAC$_D$
S40.1
COMPUTE UT_V AND $VGTIG_V$
SH4
OUTPUT: UT: INITIAL THRUST DIRECTION
VGTIG: INITIAL VALUE OF VG VECTOR
S40.2,3
COMPUTE PREFERRED IMU ORIENTATION
SH6
INPUT: UT; RTIG, REFSMMAT$_M$
OUTPUT: XSCREF$_M$: PREFERRED IMU ORIENTATION MATRIX FOR POSSIBLE IMU REALIGNMENT
INHIBIT INTER-RUPTS
PFLITE0B
ZERO ATTITUDE ERRORS, SET 1° DEADBAND
FC-1440 SH
P40SXT4
CALL ATTITUDE MANEUVER ROUTINE
SH3
OUTPUT: LM MANEUVERED TO DESIRED ATTITUDE
BURNBABY
FC-1840 SH1
TRANSFER CONTROL TO MASTER IGNITION ROUTINE
MIT
INSTRUMENTATION LAB
CAMBRIDGE MASS.
DRAWN 29OCT68
PROGR 31 Dec 68
ANALYST 10 Jan 69
DSGNR 31 OCT 68
APPR 24 Jan 68
4 May 69
P40
DPS THRUST
LUMINARY 1C
FC-3800
REV 2
SHEET 3 OF 9

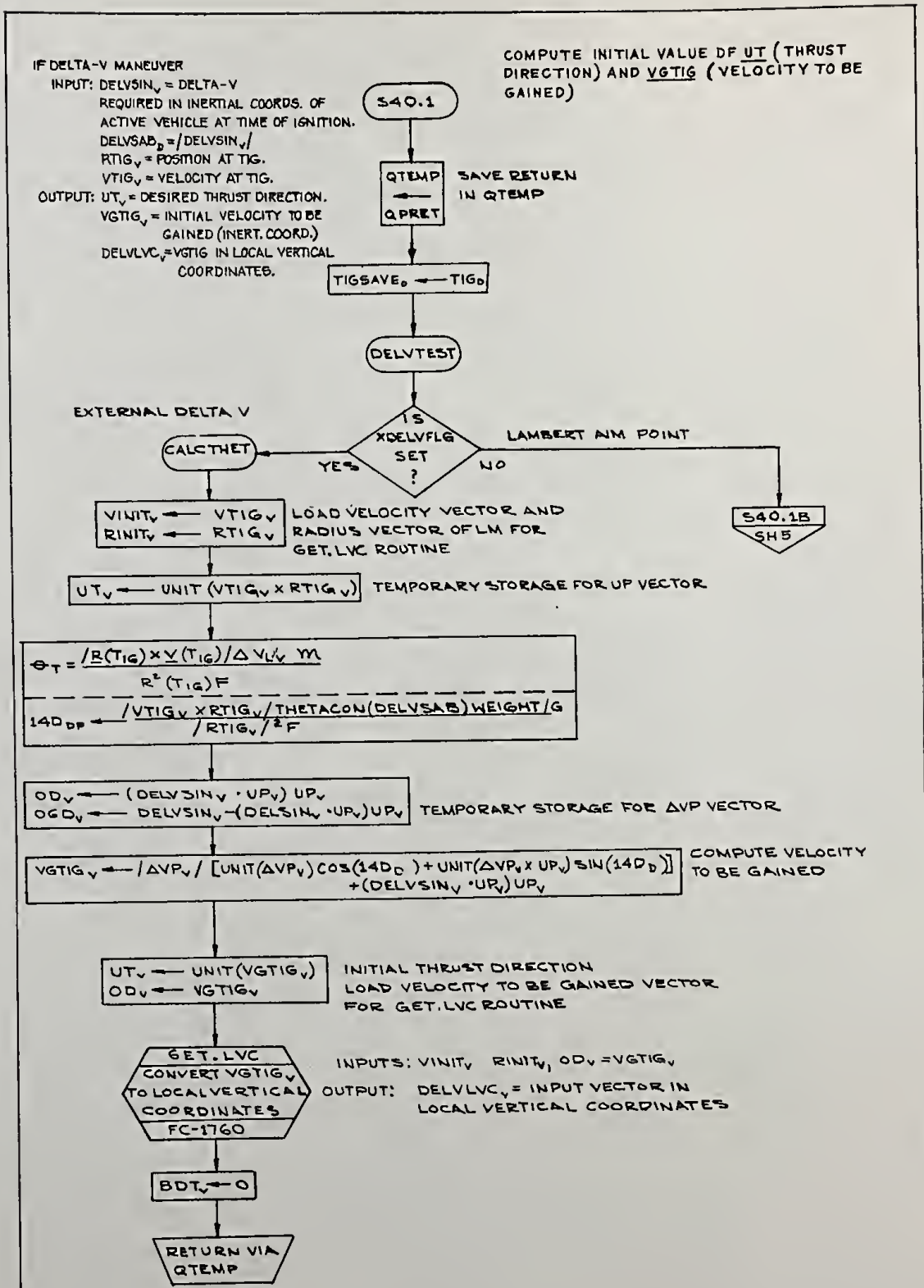


P40
DPS THRUST

W.D. Knight 7-26-68
D. Hoag 8-26-68
P. Fuller 8-5-68
M.C. Dryfoos 8-5-68
John A. Mann 24 JAN 68
16 May 69

LUMINARY 1C

FC-3800



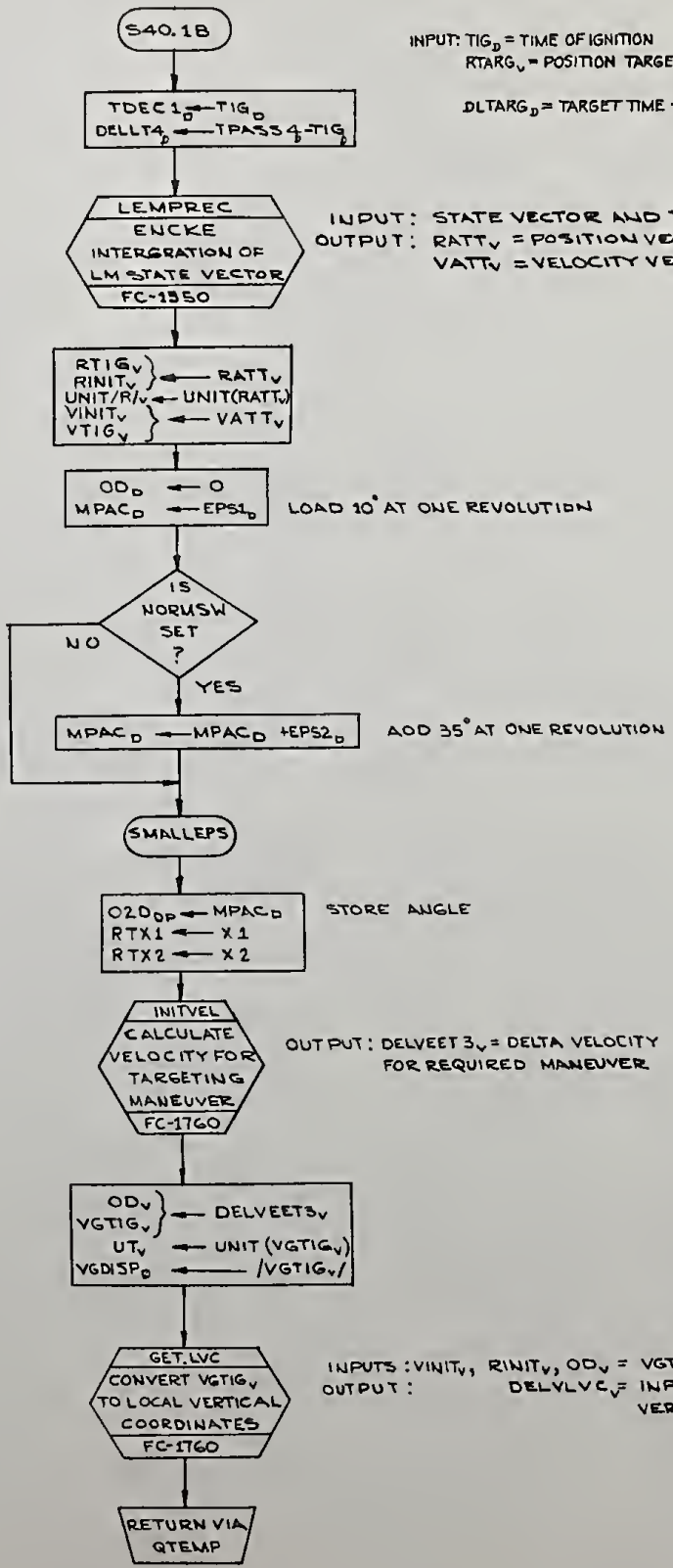
P40
DPS THRUST

W.D. Knight 7-29-68
D. Cutler 8-26-68
J. Phillips 9 Jan 69
W.C. Dwight 8-5-68
John A. Moore 24 MAY 68
16 May 69

LUMINARY 1C

FC-3800

LAMBERT AIMPOINT MANEUVER



P40
DPS THRUST

W D Knight 3-29-68
R 26 68
10 Jan 69
8-5-68
24 JAN 68
16 May 69

LUMINARY 1C

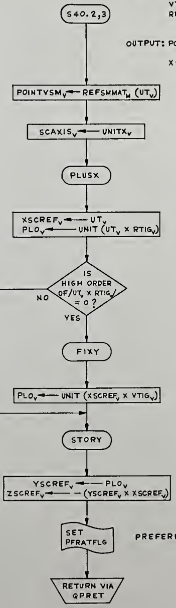
FC- 3800

2 6 9

COMPUTE PREFERRED IMU ORIENTATION MATRIX
FOR POSSIBLE IMU REALIGNMENT

INPUT: UT_V = INITIAL THRUST DIRECTION.
$RTIG_V$ = RADIUS VECTOR OF LM.
$VTIG_V$ = VELOCITY VECTOR OF LM.
$REFSMMAT_M$ = TRANSFORMATION MATRIX BETWEEN BRC SYSTEM AND STABLE MEMBER COORDINATE SYSTEM.

OUTPUT: $POINTVSM_V$ = LM THRUST DIRECTION IN SM COORDINATE.
$XSCERF_M$ = PREFERRED IMU ORIENTATION MATRIX.



TRANSFORM THRUST DIRECTION TO SM COODINATES.

PREFERRED ATTITUDE COMPUTED

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN 8 MAY 69	P40 DPS THRUST
13 MAY 69	LUMINARY 1C — DOCUMENT NO. FC-3800
16 May 69	
15 May 69	
APPROVED 16 May 69	REV 2 — SHEET 7 OF 9

SUBROUTINES IN THIS CHART

P40 SXT4	CALL ATTITUDE MANEUVER ROUTINE
S40.1	COMPUTE INITIAL THRUST DIRECTION AND VELOCITY TO BE GAINED
S40.2,3	COMPUTE PREFERRED IMU ORIENTATION

ON OTHER CHARTS

R02 BOTH	IMU STATUS CHECK
ALARM	STORE ALARM CODE
PFLITE DB	ZERO ATTITUDE ERRORS, SET 1° DEADBAND
ZATTEROR	STORE CDU DESIRED, ZERO INPUT TO AUTOPILOT
SET MINDB	SET 0.3° DEADBAND
RESTORDB	SET DEADBAND TO ASTRONUAT SELECTED VALUE
R60LEM	PERFORM AUTO ATTITUDE MANEUVER
GET. LVC	CONVERT INPUT VECTOR TO LOCAL VERTICAL COORDINATES
LEMPREC	ENCKE INTERGRATION OF LM STATE VECTOR
INITVEL	CALCULATE VELOCITY FOR TARGETING MANEUVER

FLAGS	MEANING	SET	CLEARED	TESTED
NOTHROTL	SET- INHIBIT FULL THROTTLE CLEARED - PERMIT FULL THROTTLE		SH 3	
3AXISFLG	SET- MANEUVER SPECIFIED BY THREE AXES CLEARED - MANEUVER SPECIFIED BY ONE AXIS		SH 4	
XDELVFLG	SET- EXTERNAL DELTAV VG COMPUTATION CLEARED - LAMBERT (AIMPOINT) VG COMPUTATION			SH 5
NORMSW	SET- UNIT NORMAL COMPUTED CLEARED - UNIT NORMAL NOT COMPUTED			SH 6
PFRATFLG	SET- PREFERRED ATTITUDE COMPUTED CLEARED - PREFERRED ATTITUDE NOT COMPUTED	SH 7		

DISPLAYS	MEANING	USED
V16N40	R1 - TTOGO - XXBXX MIN-SEC-TIME TO CUTOFF R2 - VGDISP - XXXX.X FT/SEC-VELOCITY TO BE GAINED R3 - D_VTOTAL - XXXX.X FT/SEC-TOTAL DELTA V	SH 4
V16N85	R1, R2, R3 } VG_V (BODY) XXXX.X FT/SEC { VGX (LM), VGY (LM), VGZ (LM) } COMPONENTS OF VG VECTOR	SH 4

ALARMS	MEANING	USED
1706	INCORRECT PROGRAM SELECTED FOR VEHICLE CONFIGURATION	SH 2

ERASABLE	MEANING	UNITS	SCALING
$VINIT_V$	VELOCITY AT TIME OF IGNITION	M/CSC	2^7
$RINIT_V$	POSITION AT TIME OF IGNITION	M	2^{29}
$VGTIG_V$	INITIAL VELOCITY TO BE GAINED	M/CSEC	2^7
UT_V	DESIRED THRUST DIRECTION	UNIT VECTOR	2^1
$XSCREF_V$	WINGS-LEVEL HEAD-UP	UNIT VECTOR	2^1
$YSCREF_V$	LM ORIENTATION IN	UNIT VECTOR	2^1
$ZSCREF_V$	REFERENCE COORDINATES	UNIT VECTOR	2^1
F_D	ENGINE THRUST	M-NEWTONS*	2^7
$TDECAY_D$	AT TAIL-OFF TIME TIME OF ENGINE	CSEC	2^{28}

* M-NEWTONS = 10^6 NEWTONS

P40
DPS THRUST

W D Knight 7-26-68
P Adley 8-26-68
P Hoffman 10 Jan 69
W C Dughlett 8-5-68
John A. Moore 24 Mar 68
16 May 69

LUMINARY 1C

FC-3800

2 8 9

FIXED CONSTANTS	MEANING	PHYSICAL VALUE & UNITS	STORED VALUE & UNITS	SCALING
$FDPS_D$	DPS ENGINE THRUST	9712.5 POUNDS	4.319223105 M-NEWTONS*	2^7
$THETA\ CON_D$	$1/\pi$ CONVERSION FACTOR	$1/\pi$ 1/RAD	.31830989 1/RAD	2^8
$TDECAY_D$	DPS ENGINE $\Delta T_{TAIL-OFF}$ TIME	0.08 SEC	-8 CSEC	2^{28}

*M-NEWTONS = 10^4 NEWTONS

ADDED FLAG FOR P40 DPS THRUST

FLAG	MEANING WHEN SET	MEANING WHEN CLEAR	WHERE SET	WHERE CLEARED	WHERE TESTED
BIT 13 OF DAPBOOLS	CSM DOCKED	CSM IS NOT DOCKED			SH3
APSFLAG	ASCENT STAGE	DESCENT STAGE			SH2

W. D. Knight 8-5-68
8-26-68
10 Jan 69
8-5-68
24 Jan 68
16 May 69

P40
DPS THRUST

LUMINARY 1C

FC-3800

P41 RCS THRUST

MAJOR SUBROUTINES ON THIS CHART

P41LM	P41 RCS THRUST PROGRAM	SH2
CALCN85	CALL VG CALCULATION	SH5
S41.1	TRANSFORM VECTOR FROM REF. COORD TO BODY AXIS	SH5
UPDATEVG	UPDATE VG CALCULATION	SH5

MIT
INSTRUMENTATION LAB
CAMBRIDGE, MASS.

APOLLO
GUIDANCE AND NAVIGATION

DRAWN 30 MAY 68
PROGMR
ANALST
DSGNR
APPD

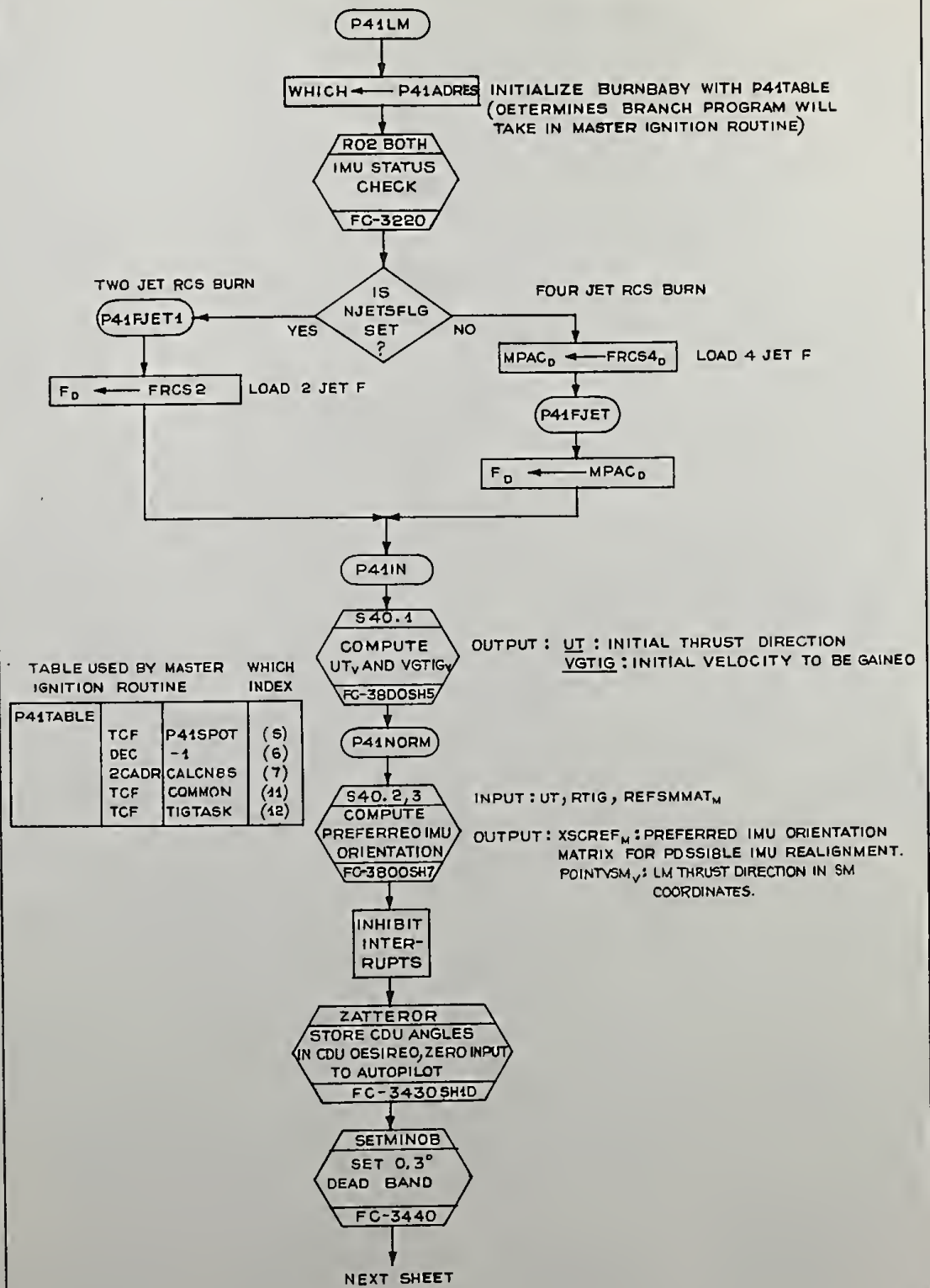
P41 RCS THRUST

LUMINARY 1C

DOCUMENT NO. FC-3810

REV 1

PAGE 1 OF 14



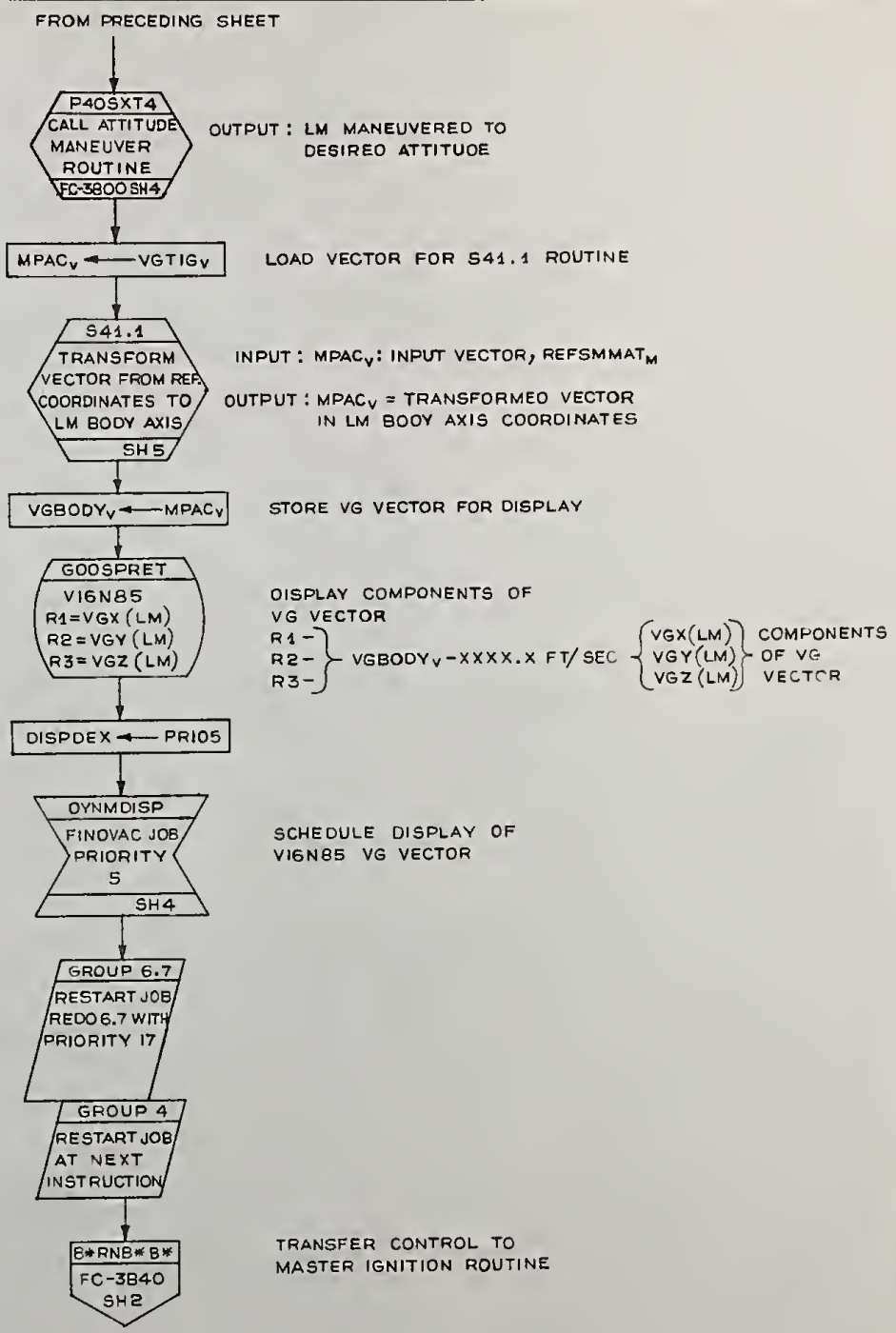
P41
RCS THRUST

P. M. Dichter 30JUL68
D. Cooley 8-6-68
D. Phillips 10 Jan 69
W. Dargett 26 Nov.
John A. Moore 24JAN 68

LUMINARY IC ..AF

FC-3810

1 2 14



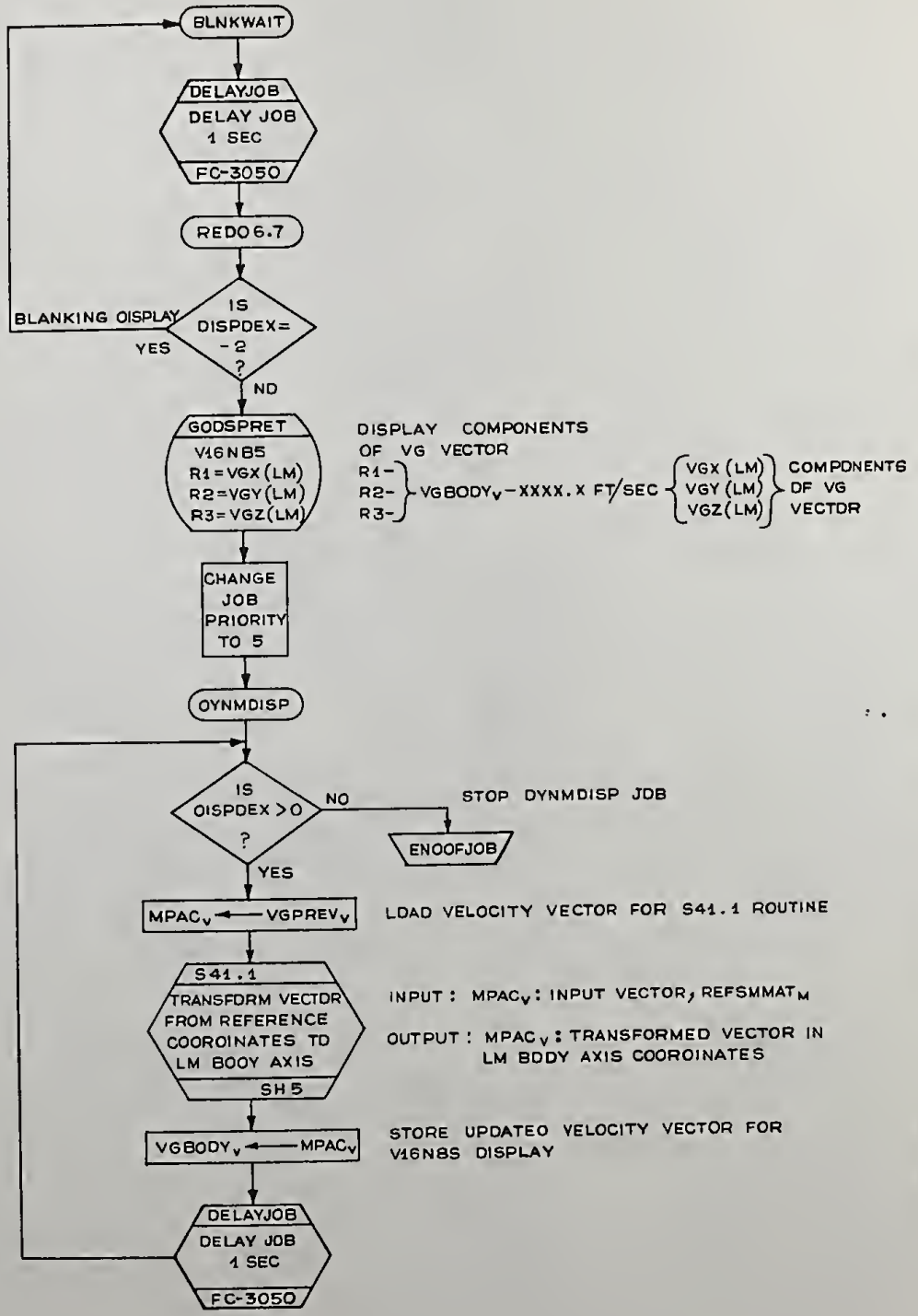
P41
RCS THRUST

30JUL68
8-26-68
10JAN-69
26AUG68
24 JAN 68

LUMINARY 1C

FC-3810

1 3 14

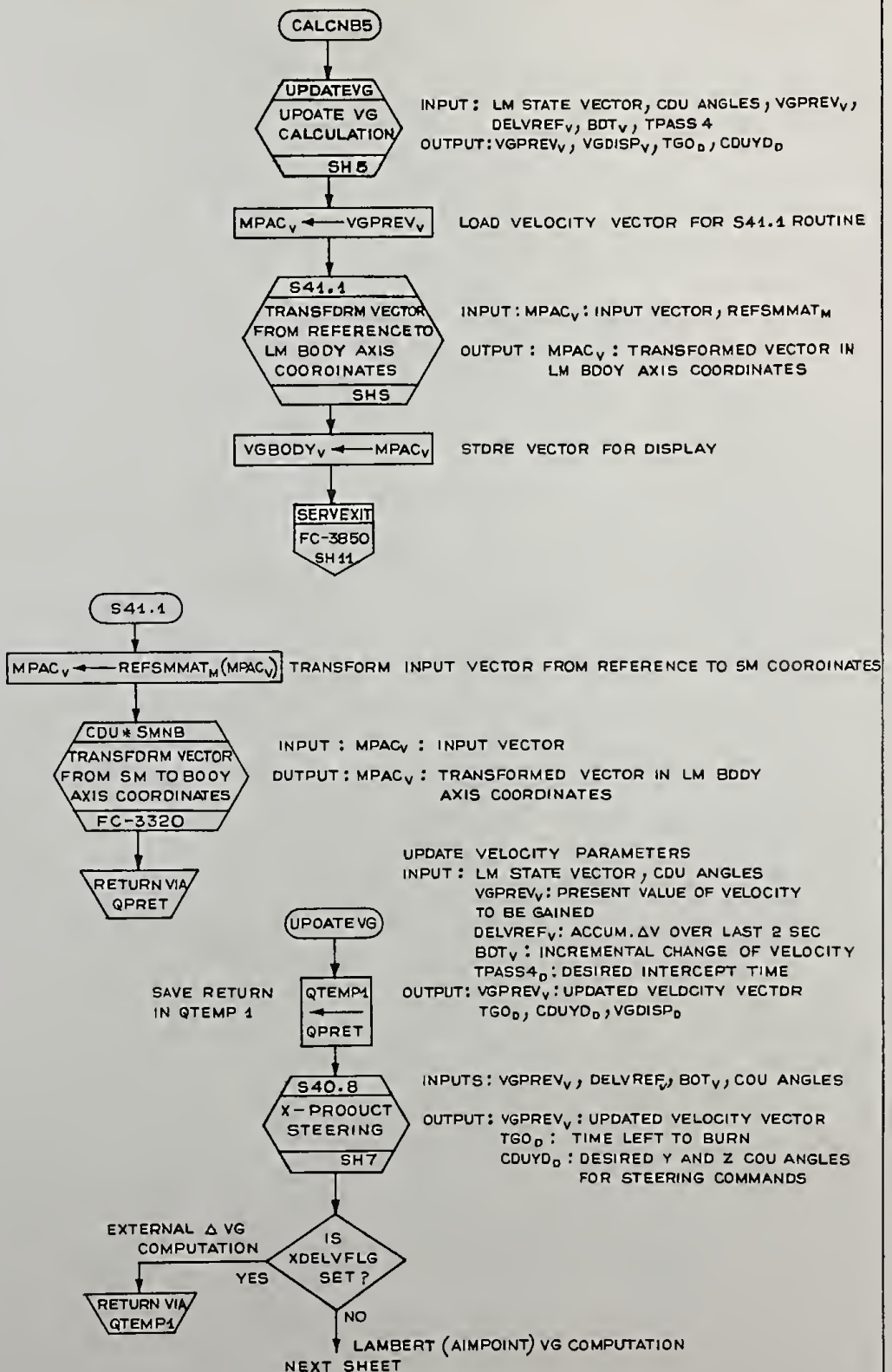


P41
RCS THRUST

LUMINARY 1C

FC-3810

4 14

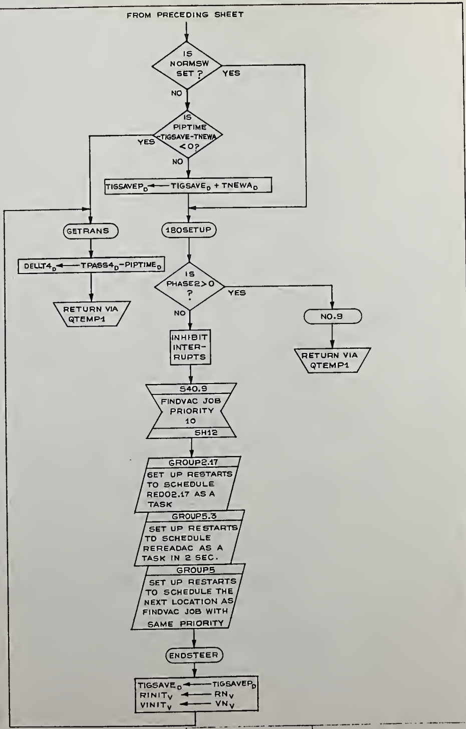


P41
RCS THRUST

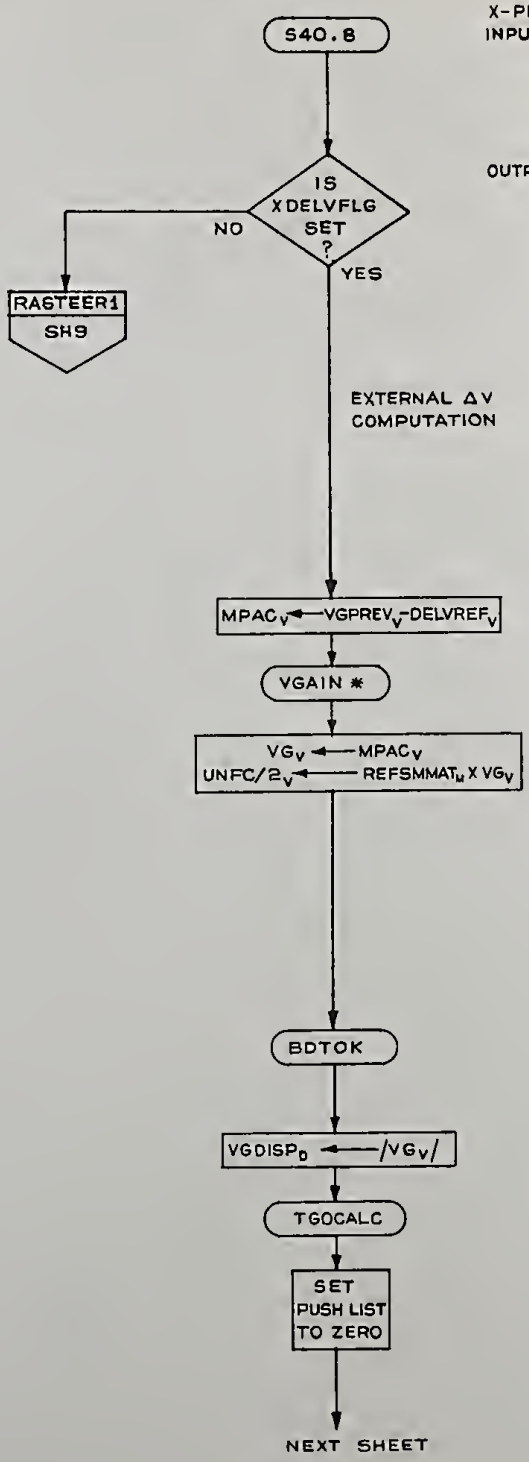
P. M. Dietrich 31JUL68
C Allen 2AUG68
D Phillips 10JUL69
MC Dougherty 26AUG68
John A. Moore 24JUL69

LUMINARY 1C FC-3810

1 5 14



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN [signature] BOMAYES	P41 RCS THRUST
[signature] 17June69	LUMINARY 1C
ANALYST	DOCUMENT NO FC-3810
[signature] 17June69	
APPR'D [signature] 17June69	REV 1 — SHEET 6 OF 14



X-PRODUCT STEERING

INPUTS : $VGPREV_V$: PRESENT VALUE OF VELOCITY TO BE GAINED VECTOR
$DELVREF_V$: ACCUMULATED ΔV OVER LAST 2 SEC

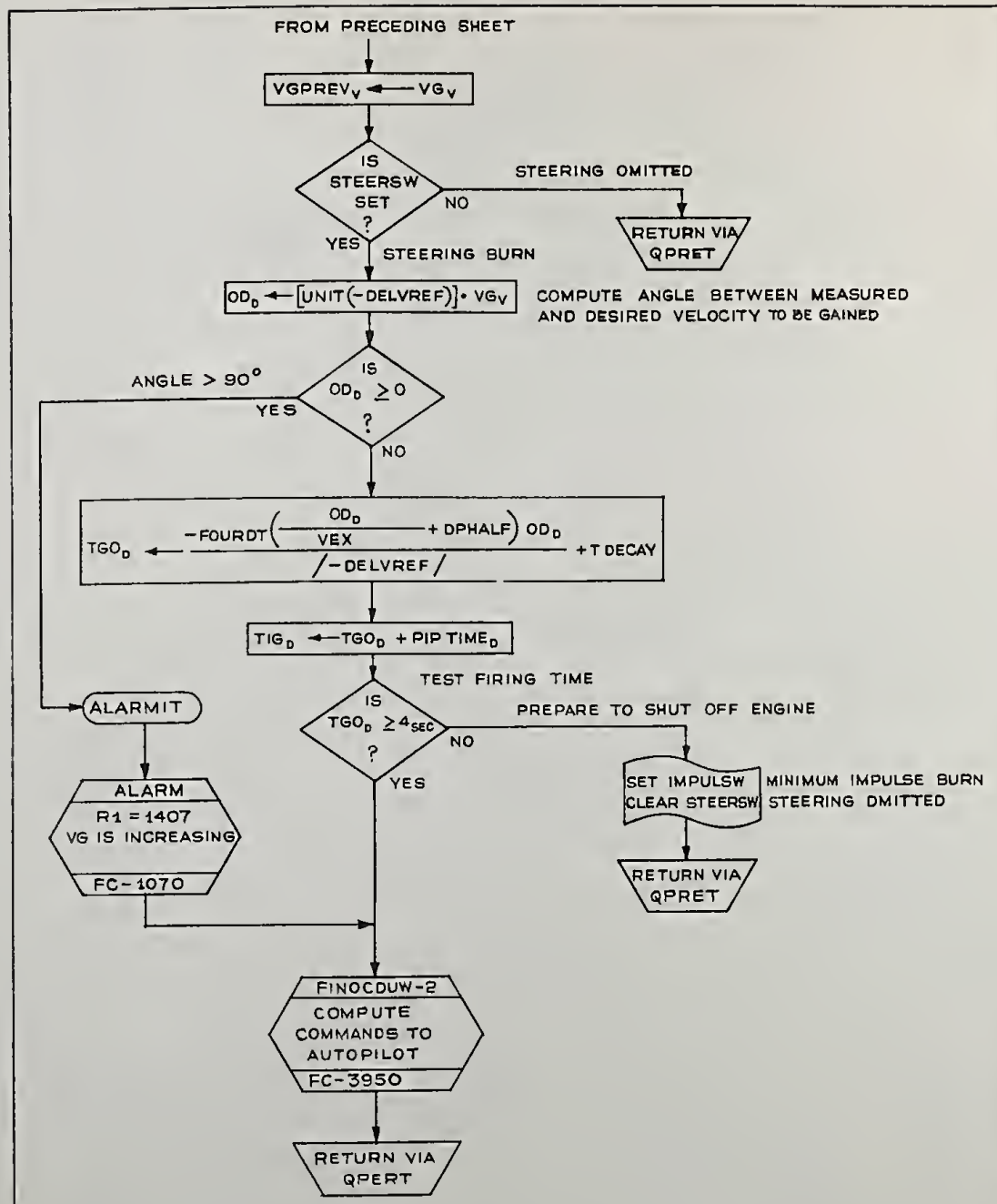
OUTPUT : $VGPREV_V$: UPDATED VALUE OF VELOCITY TO BE GAINED VECTOR
TGO_D : TIME LEFT TO BURN
$CDUYD_D$: DESIRED Y & Z CDU ANGLES FOR STEERING COMMANDS

P41
RCS THRUST

P.M. Dietrich 31JUL68
C Adler 8-26-68
D Phillips 10 Jan 69
John A Moore 24 JAN 69

LUMINARY 1C FC-3810

1 7 14

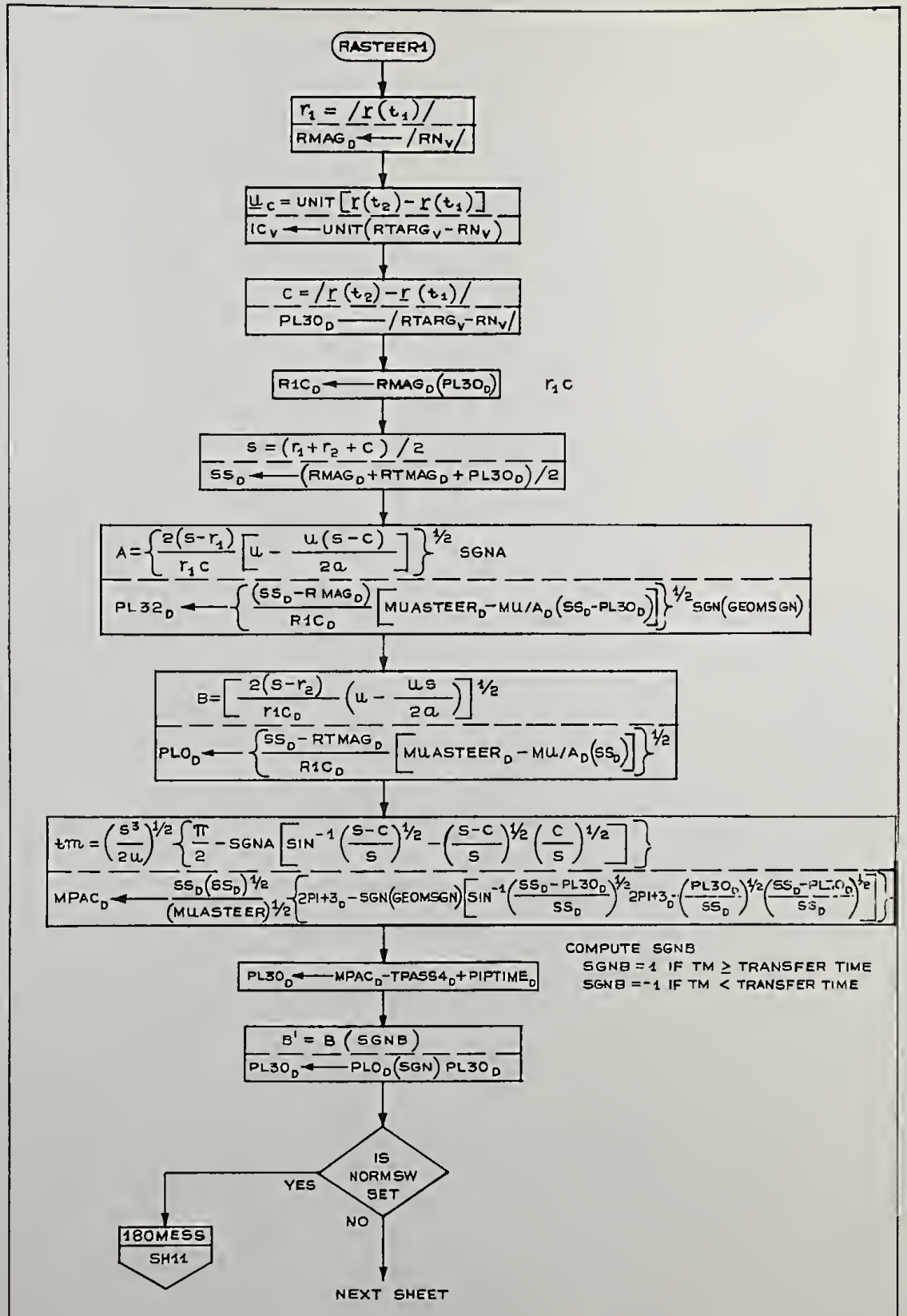


P41
RCS THRUST

D. Dietz 1 AUG 68
D. Fuller 8-26-68
D. Phillips 10 Jan 69
M.C. Dyfrid 26 NOV
John A. Moss 27 JAN 69

LUMINARY 1C

FC-3810



MIT
INSTRUMENTATION LAB
CAMBRIDGE, MASS.

DRAWN 2JUNE69

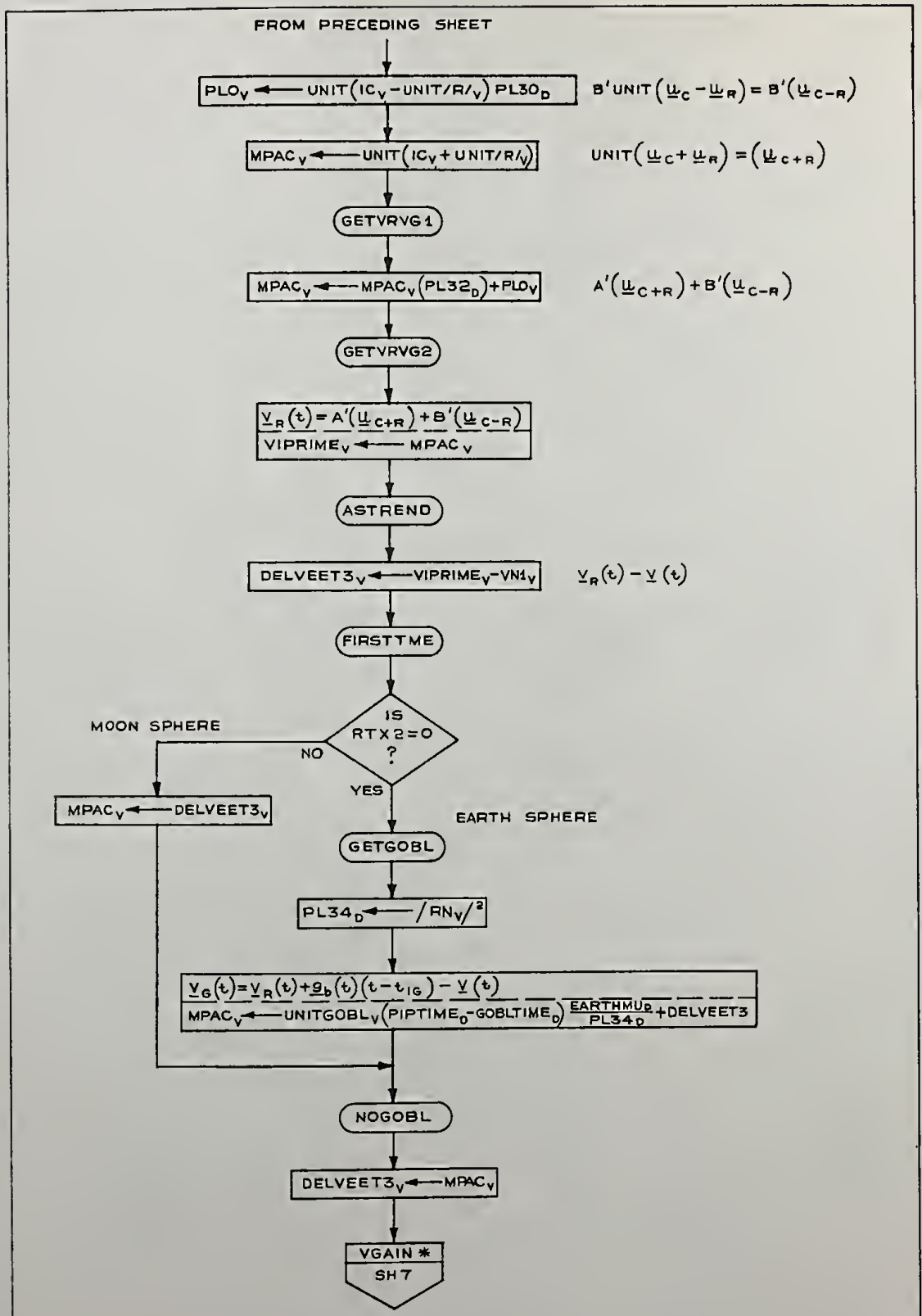
P41
RCS THRUST

LUMINARY 1C

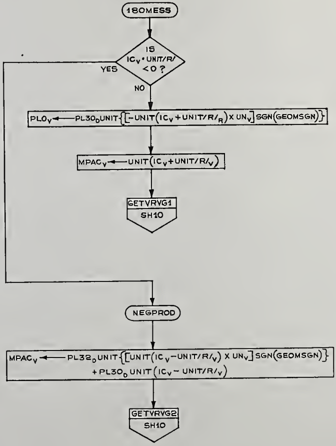
FC-3810

REV 1

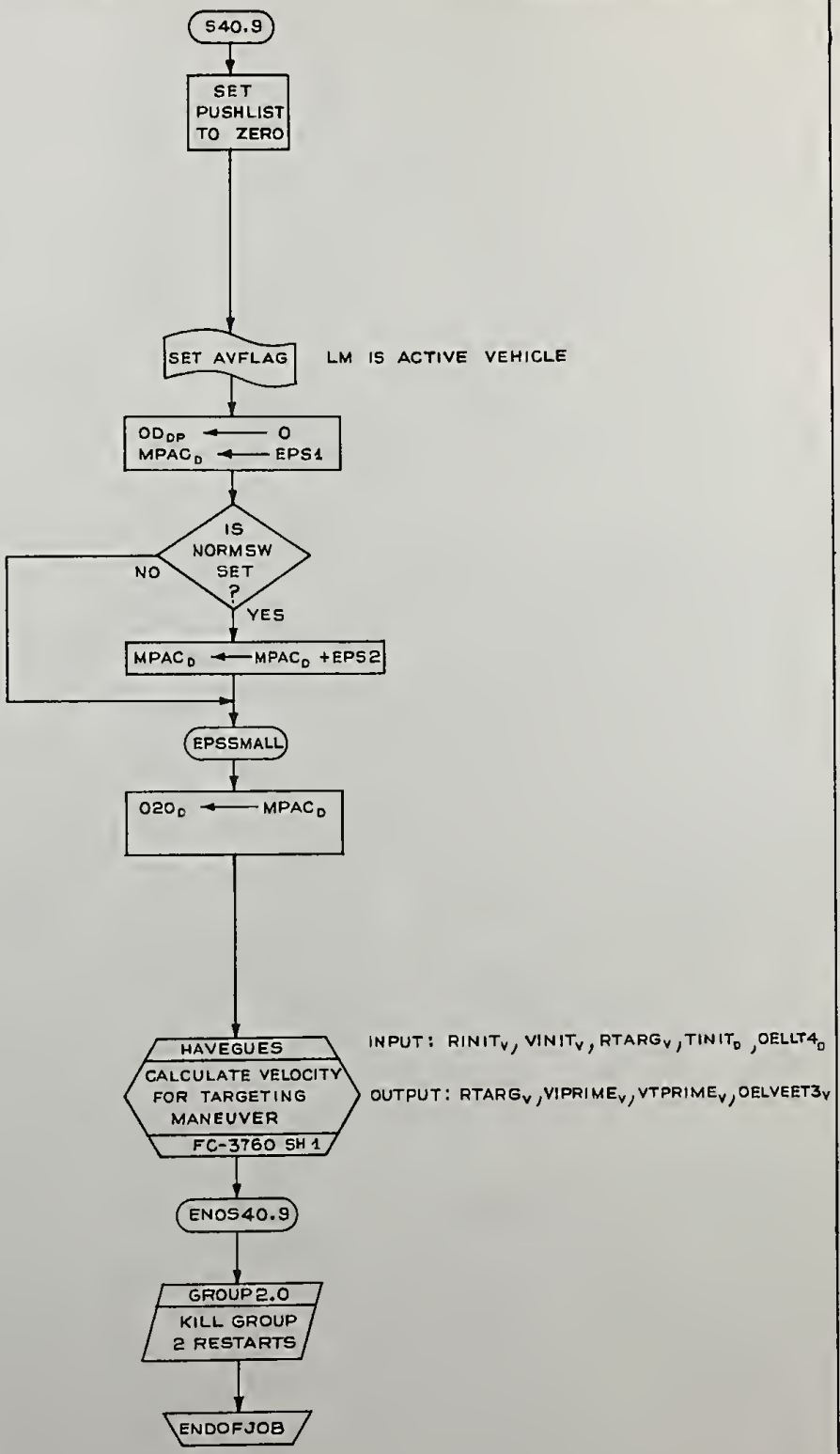
9 14



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE & NAVIGATION
DRAWN R.H. Richter 2 JUNE 69	P41 RCS THRUST
PROGR D. Adler 7 June 69	
ANALYST	LUMINARY 1C
DOCMR M. C. Crisp 7 JUNE 69	DOCUMENT NO. FC-3810
APPR'D Alex M. Scott 7 JUNE 69	REV 1 SHEET 10 OF 14



MIT INSTRUMENTATION LAB CAMBRIDGE MASS	APOLLO GUIDANCE AND NAVIGATION
DRAWN P.M. Diotte 2JUNE69	P41 RCS THRUST
CHECKED P. Gallu 17June69	LUMINARY 1C
ANAL	DOCUMENT NO. FC-3810
APPROVED M. Douglass 17JUNE69	
APPROVED [illegible] 17JUNE69	REV 1 SHEET 11 OF 14



P41
RCS THRUST

P Y Dieterich 2 AUG 68
P Fuller 8 AUG 68
P Phillips 10 AUG 68
R C Doggett 26 AUG 68
John R Moore 24 JAN 69

LUMINARY 1C

FC-3810

1 12 14

SUBROUTINES

ON THIS CHART

S41.1	TRANSFORM VECTOR FROM REF. COORDINATES TO BODY AXIS
CALCNB5	CALL VG CALCULATION UPDATE
UPDATEVG	UPDATE VG CALCULATION
S40.8	X-PRODUCT STEERING
S40.8	COMPUTE VELOCITY, VELOCITY-TO-BE-GAINED AND B VECTORS

ON OTHER CHARTS

RO2BOTH	IMU STATUS CHECK
S40.1	COMPUTE UT AND VGTIG VECTORS
S40.2,3	COMPUTE PREFERRED IMU ORIENTATION
ZATTEROR	STORE CDU ANGLES IN COU DESIRED, ZERO INPUT TO AUTOPILOT
SETMINDB	SET 0.3° DEADBAND
P40SXT4	CALL ATTITUDE MANEUVER ROUTINE
DELAYJOB	DELAY SCHEDULED JOB
TMPTOSPT	LOAD CDUS CORRESPONDING TO PIPTIME IN COUSPOT VECTOR
TRG*SMNB	TRANSFORM FROM SM TO NB COORDINATES
SMNB	TRANSFORM FROM SM TO NB COORDINATES
V1STO2S	CONVERT 1'S COMPLEMENT ANGLES TO 2'S COMPLEMENT ANGLES
ALARM	DISPLAY ALARM CODE
HAVEGUES	CALCULATE VELOCITY FOR TARGETING MANEUVER

FLAGS	MEANING	SET	CLEARED	TESTED
NJETSFLG	SET-TWO JET RCS BURN CLEARED - FOUR JET RCS BURN			SH 2
XDELVFLG	SET-EXTERNAL DELTAV VG COMPUTATION CLEARED - LAMBERT (AIMPOINT) VG COMPUTATION			SH 5,7
STEERSW	SET - STEERING TO BE DONE CLEARED - STEERING OMITTED		SH 8	SH 8
IMPULSW	SET - MINIMUM IMPULSE BURN CLEARED - STEERING BURN	SH 8		
AVFLAG	SET - AVERAGE G (SERVICER) DESIRED CLEARED - AVERAGE G (SERVICER) NOT DESIRED	SH 12		
NORMSW	SET - UNIT NORMAL COMPUTED CLEARED - UNIT NORMAL NOT COMPUTED			SH 6,9,12

DISPLAY	MEANING	USED
V16N85	R1- R2- R3- } VG_V(BODY) XXXX.X FT/SEC { VGX(LM) VGY(LM) VGZ(LM) } COMPONENTS OF VG VECTOR	SH 3,4

ALARMS	MEANING	USED
1407	VG IS INCREASING	SH 8

P. N. Dietrich 6AUG68
D. Griffin 8-26-68
P. Phillips 10 Jan 69
M. C. Dougherty 2 Dec
John A. Mars 24 JAN 69

P41
RCS THRUST
LUMINARY 1C

ERASABLES	MEANING	UNITS	SCALING
F_D	THRUST FOR ENGINE USED	* M – NEWTONS	2^{7}
$VGBODY_V$	VELOCITY TO BE GAINED VECTOR (BODY COORDS)	M/CSEC	2^{7}
VG_V	VELOCITY TO BE GAINED VECTOR	M/CSEC	2^{7}
$AXID_V$	OESIRED THRUST DIRECTION	UNIT VECTOR	2^{1}
$VGDISP_D$	MAGNITUOE OF VELOCITY TO BE GAINED VECTOR FOR DISPLAY	M/CSEC	2^{7}
$VGPREV_V$	VELOCITY TO BE GAINEO VECTOR (PREVIOUS)	M/CSEC	2^{7}
TGD_D	TIME LEFT TO BURN	CSEC	2^{28}
TIG_D	TIME OF IGNITION	CSEC	2^{28}
$AXIS_V$	ACTUAL THRUST DIRECTION	UNIT VECTOR	2^{1}
$RINIT_V$	ACTIVE VEHICLE RADIUS VECTOR	METERS	2^{29}
$VINIT_V$	ACTIVE VEHICLE VELOCITY VECTOR	M/CSEC	2^{7}
$TNIT_D$	TIME OF STATE VECTOR	CSEC	2^{28}
$DELLT4_D$	REMAINING TIME TILL INTERCEPT	CSEC	2^{28}
$DELVEET3_V$	VELOCITY TO BE GAINEO	M/CSEC	2^{7}
BDT_V	INCREMENTAL CHANGE OF THE VELOCITY TO BE GAINED VECTOR OUE TO RATE OF CHANGE OF VELOCITY REQUIRED AND GRAVITY VECTOR. THIS IS Q_V FOR EXTERNAL ΔV.	M/CSEC	2^{7}

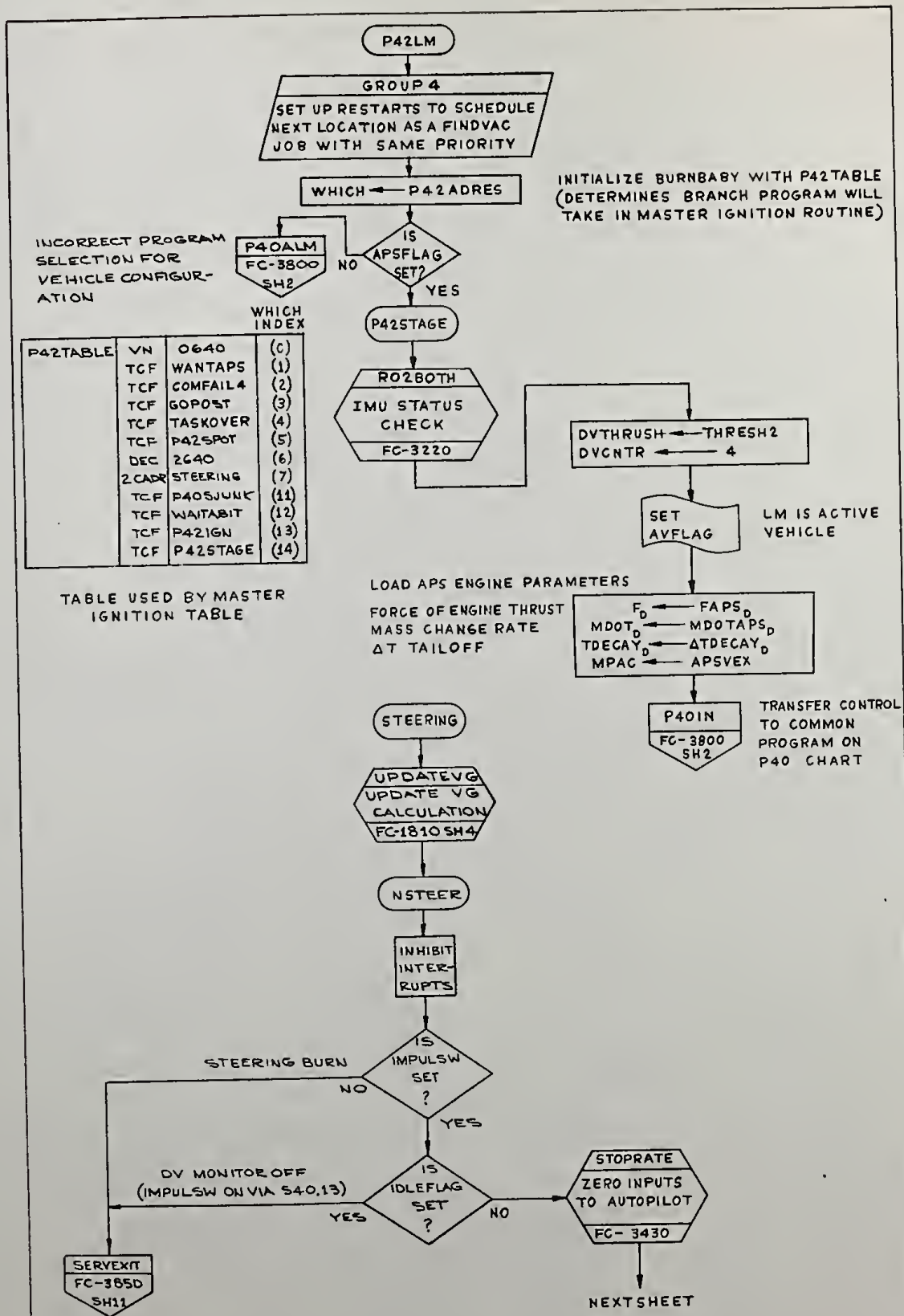
* M-NEWTONS = 10^4 NEWTONS

P42
APS THRUST

MAJOR SUBROUTINES ON THIS CHART

P42LM	APS THRUST PROGRAM	SH 2
STEERING	SERVICER EXIT FOR STEERING BURN	SH 2
GETDT	STORE INPUT A IN TGO + 1	SH 3

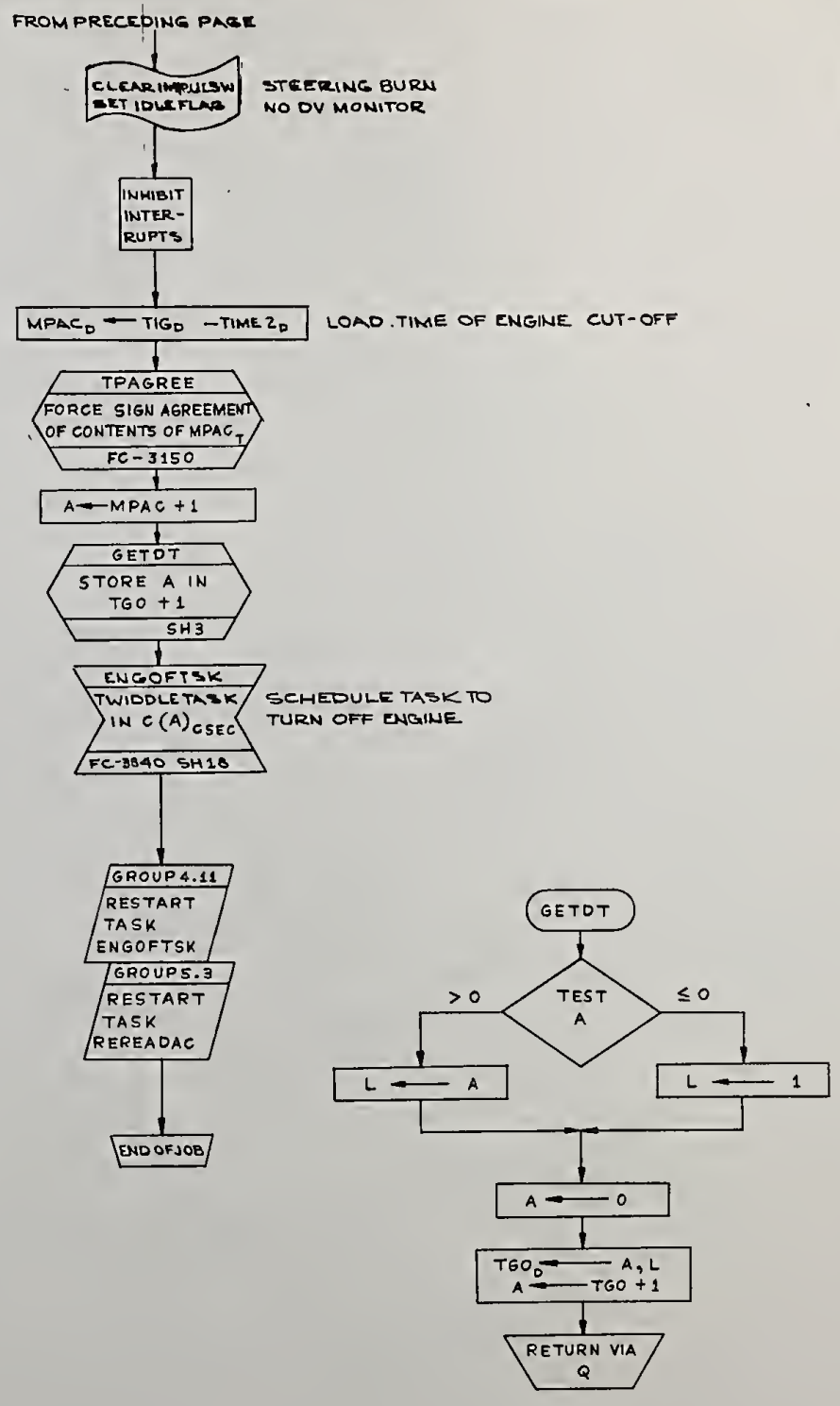
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	8 MAY 69	P42 APS THRUST	
PROG	13 May 69		
ANALST	16 May 69	LUMINARY 1C	DOCUMENT NO. FC-3820
DOCMR	17 May 69		
APPR'D	16 May 69	REV 2	SHEET 1 OF 4



P42
APS THRUST

LUMINARY 1C

FC-3820
2 4



P4-2
APS THRUST

W D Knight 7-29-68
P Adler 8-28-68
P Phillips 10 Jan 69
W C Wright 8-28-68
John A. Moss 24 JAN 69
16 May 69

LUMINARY 1C

FC-3820

1 3 4

SUBROUTINES
ON THIS CHART
STEERING SERVICER EXIT FOR STEERING BURN

ON OTHER CHARTS
R02 BOTH IMU STATUS CHECK
UPDATEVG UPDATE VG CALCULATION
TPAGREE FORCE SIGN AGREEMENT OF CONTENTS OF MPAC $_T$

FLAGS	MEANING	SET	CLEARED	TESTED
AVFLAG	SET - LM IS ACTIVE VEHICLE CLEARED - CSM IS ACTIVE VEHICLE	SH2		
IMPULSW	SET - MINIMUM IMPULSE BURN CLEARED - STEERING BURN		SH3	SH2
IDLEFLAG	SET - NO DV MONITOR CLEARED - CONNECT DV MONITOR	SH3		SH2

ERASABLE	MEANING	UNITS	SCALING
F	THRUST FOR ENGINE USED	M-NEWTONS*	2^{7}
MOOT	MASS CHANGE RATE	KG/CSEC	2^{3}
TDECAY	DELTA-T TAILOFF	CSEC	2^{28}
TGO	TIME OF ENGINE CUT-OFF	CSEC	2^{28}

*M-NEWTONS = 10^{4} NEWTONS

FIXED CONSTANTS	MEANING	PHYSICAL VALUE & UNITS	STORED VALUE & UNITS	SCALING
$FAPS_D$	APS ENGINE THRUST	3500 POUNDS	1.5568 M-NEWTONS *	2^{7}
$MDOTAPS_D$	APS ENGINE MASS CHANGE RATE	5.14 KG/SEC	.0513781393 KG/CSEC	2^{3}
$\Delta TDECAY_D$	APS ENGINE ΔT TAIL-OFF	-0.07 SEC	-7 CSEC	2^{28}

WOCKNIGHT 7-29-68
8-29-68
10 Jan 69
8-28-68
John E Morse 24 JAN 69
16 May 69

P42
APS THRUST

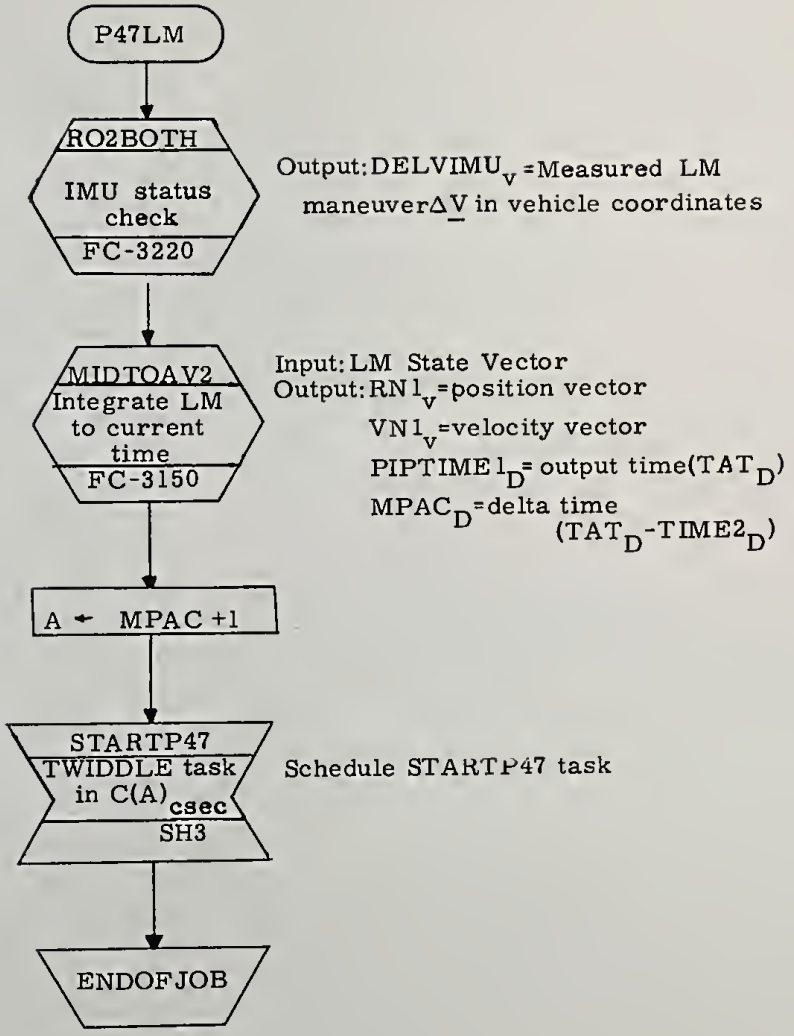
LUMINARY 1C

FC-3820

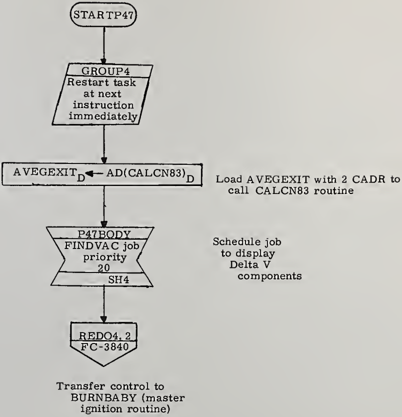
P47 THRUST MONITOR

P47LM	SH. 2
CALCN83	SH. 5

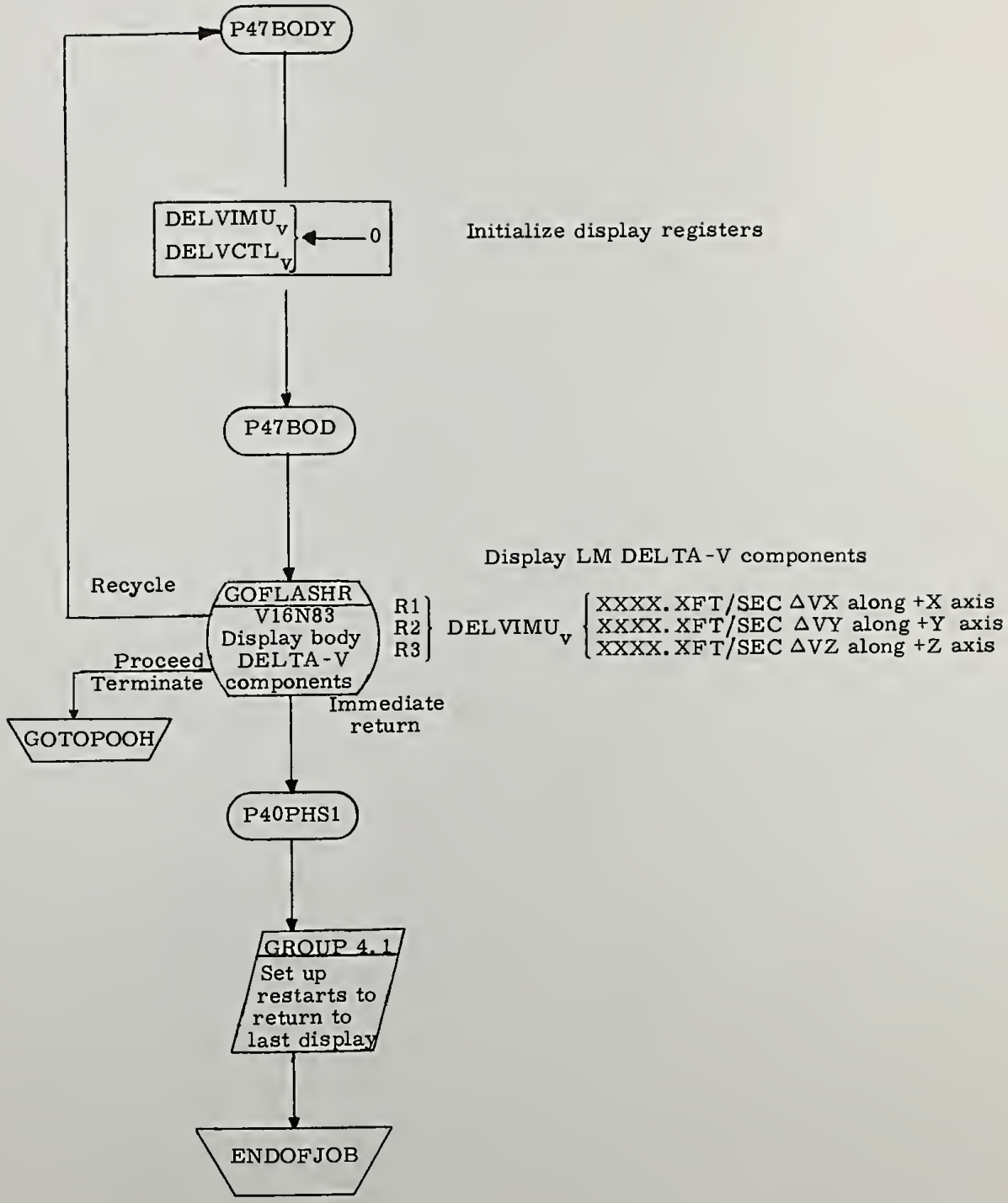
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN J. Cincotta	8Aug68	P47 THRUST MONITOR	
PRGMR P. Adler	8Aug68	LUMINARY 1C	DOCUMENT NO. FC-3830
ANALST			
DOCMR W C Danforth	8AUG68	REV 2	SHEET 1 OF 5
APPR'D			



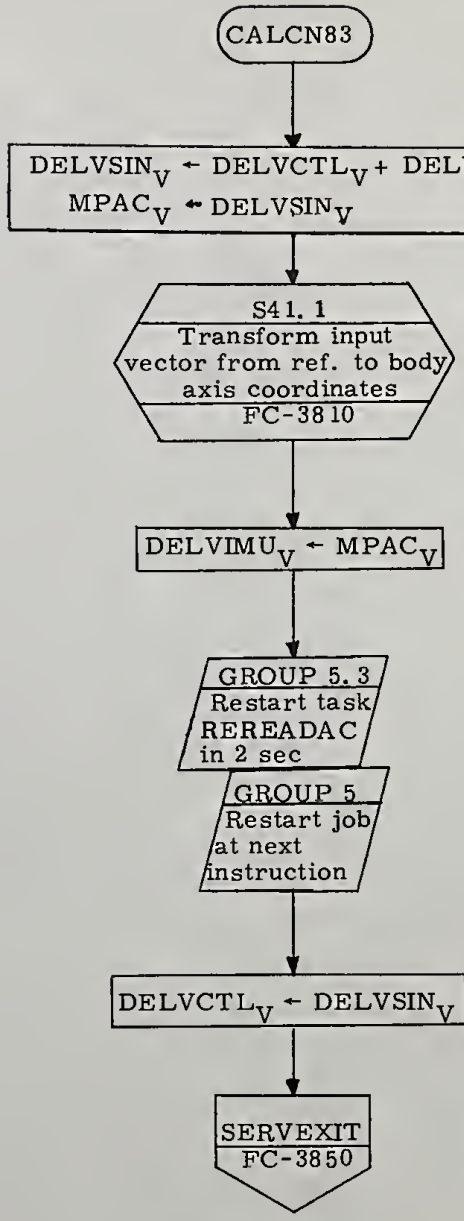
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN J Crocker	8 Aug 69	P47 Thrust Monitor	
PRGMR [illegible]	[illegible]		
ANALST			
DOCMR W C Duffeth	5 Aug 69	LUMINARY 1C	DOCUMENT NO. FC-3830
APPR'D [illegible]	[illegible]	REV 2	SHEET 2 OF 5



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN J. Cmcotta	6 Aug 69	P47 Thrust Monitor	
PRGMR P. Volante	14 Aug 69		
ANALST		LUMINARY 1C	DOCUMENT NO. FC-3830
DOCMR W C Dodsworth	5 Aug 69		
APPR'D		REV 2	SHEET 3 OF 5



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN J. Cicco	5 Aug 69	P47 Thrust Monitor	
PRGMR P. Adler	5 Aug 69		
ANALST		LUMINARY 1C	DOCUMENT NO. FC-3830
DOCMR M. Copeland	5 AUG 69		
APPR'D		REV 2	SHEET 4 OF 5



DELVCTL$_V$ = LM velocity components in reference coordinates

Input: MPAC$_V$: input vector, REFSMMAT, CDUX, CDUY, CDUZ
Output: MPAC$_V$: transformed vector in body coordinates

Store velocity components for display by V16N83

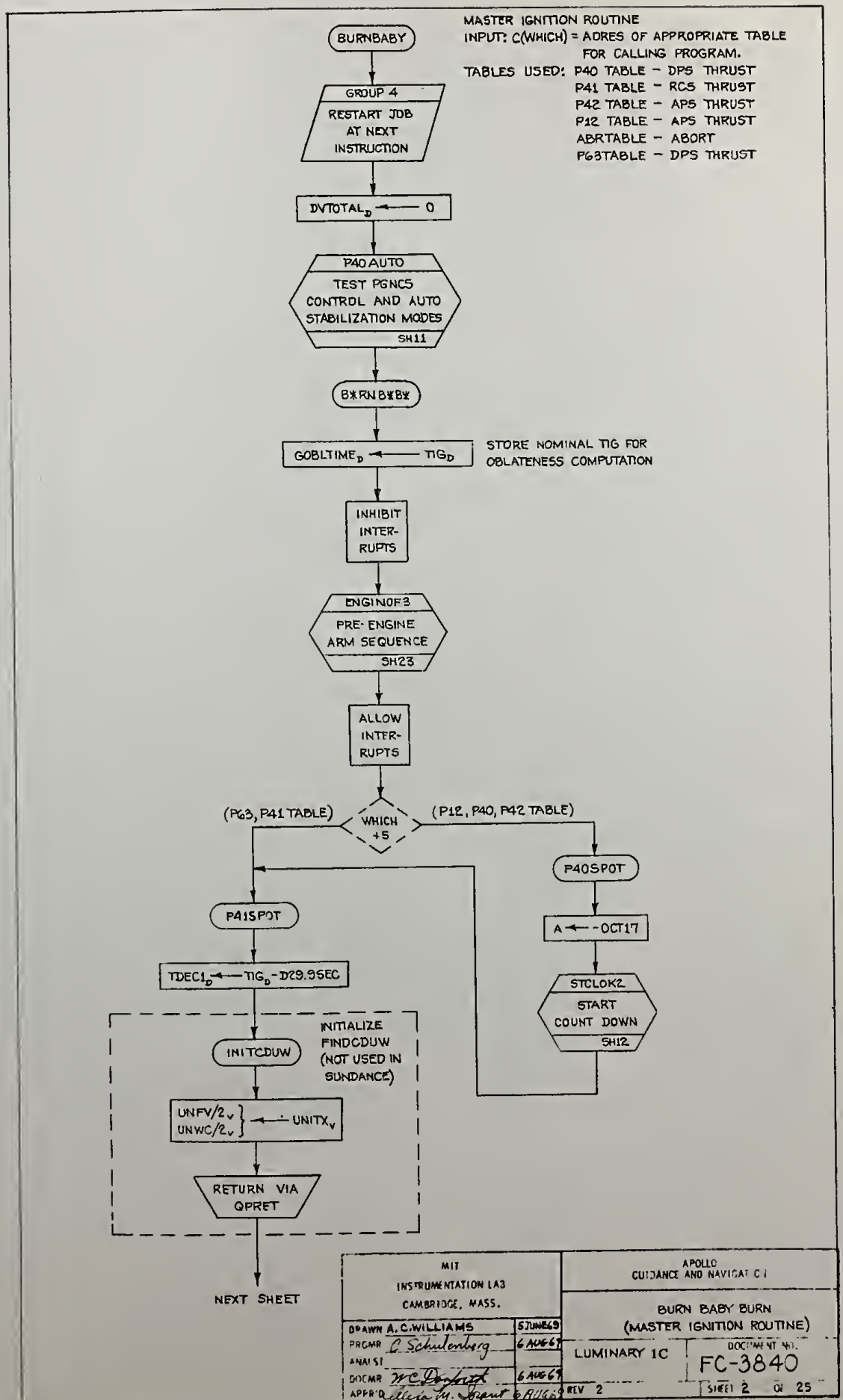
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN J. Cincotta	5 Aug 68	P47 Thrust Monitor	
PRGMR P. Adler	4 Aug 68		
ANALST		LUMINARY 1C	DOCUMENT NO. FC-3830
DOCMR W. C. Eyhorst	5 AUG 68	REV 2	SHEET 5 OF 5
APPR			

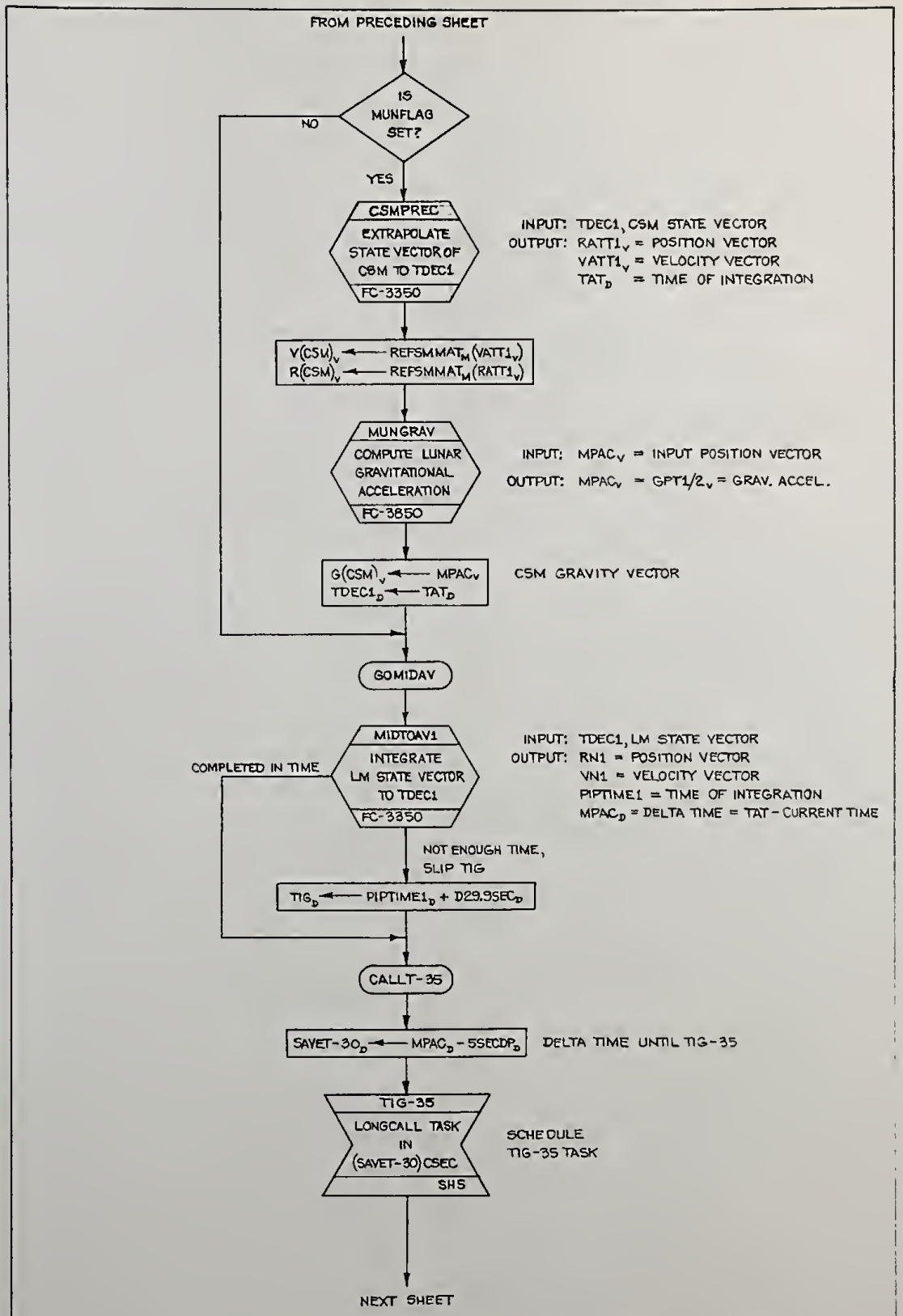
BURN BABY BURN
(MASTER IGNITION ROUTINE)

MAJOR SUBROUTINES ON THIS CHART

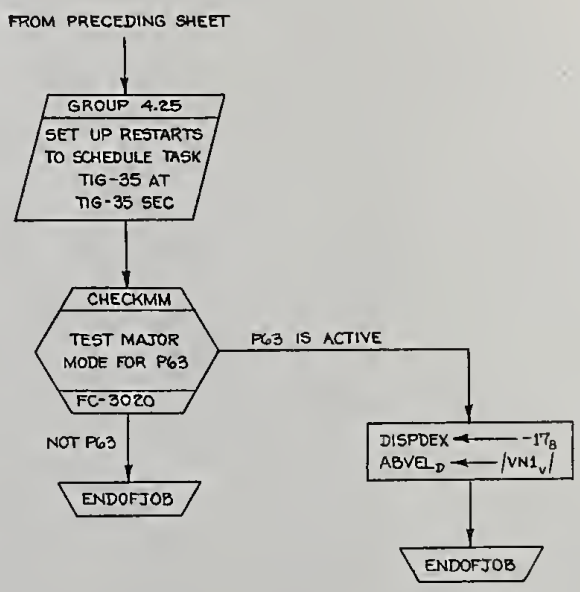
BURNBABY	Sh. 2
ENGINOF2	Sh. 13
P40AUTO	Sh. 11
STCLOK1	Sh. 12

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.			APOLLO GUIDANCE AND NAVIGATION	
DRAWN	K Wild	6/0-/69	Burn Baby Burn (Master Ignition Routine)	
PRGMR	P Allen	6/9/69		
ANALST			LUMINARY 1C	DOCUMENT NO. FC-3840
DOCMR	J E Dayhoff	10/9/69		
APPR'D	Robert M. Eutel	10/9/69	REV 2	SHEET 1 OF 25

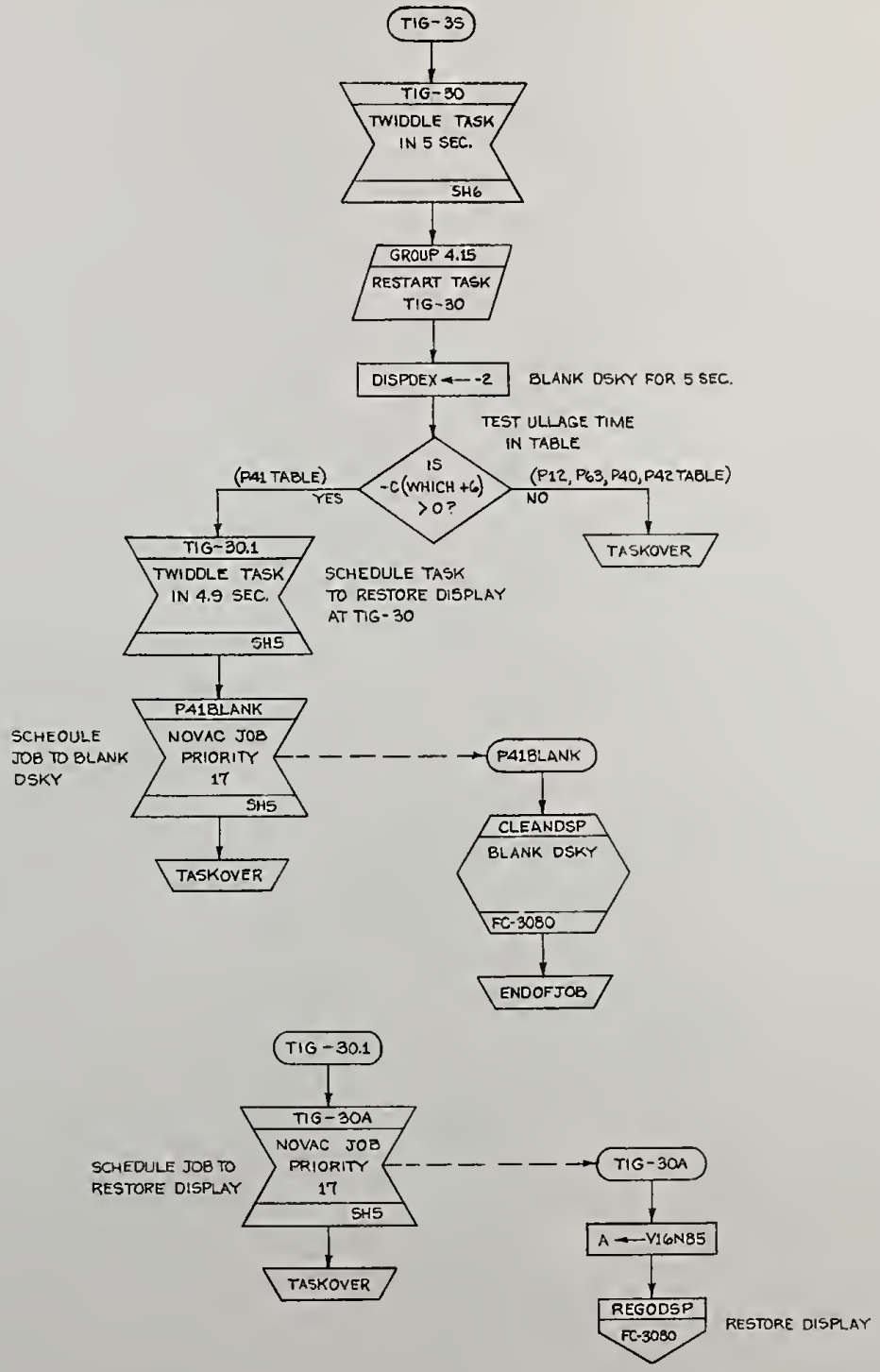

MASTER IGNITION ROUTINE
INPUT: C(WHICH) = ADRES OF APPROPRIATE TABLE FOR CALLING PROGRAM.
TABLES USED: P40 TABLE - DPS THRUST
P41 TABLE - RCS THRUST
P42 TABLE - APS THRUST
P12 TABLE - APS THRUST
ABRTABLE - ABORT
P63TABLE - DPS THRUST
BURNBABY
GROUP 4
RESTART JOB AT NEXT INSTRUCTION
DVTOTAL_D ← 0
P40AUTO
TEST PGNCS CONTROL AND AUTO STABILIZATION MODES
SH11
B*RNB*B*
GOBLTIME_D ← TIG_D
STORE NOMINAL TIG FOR OBLATENESS COMPUTATION
INHIBIT INTER-RUPTS
ENGINOF3
PRE-ENGINE ARM SEQUENCE
SH23
ALLOW INTER-RUPTS
(P63, P41 TABLE)
WHICH +5
(P12, P40, P42 TABLE)
P40SPOT
A ← -OCT17
STCLOK2
START COUNT DOWN
SH12
P41SPOT
TDEC1_D ← TIG_D - D29.9SEC
INITIALIZE FINDCDUW (NOT USED IN SUNDANCE)
INITCDUW
UNFV/2_V
UNWC/2_V
← UNITX_V
RETURN VIA QPRET
NEXT SHEET
MIT
INSTRUMENTATION LAB
CAMBRIDGE, MASS.
APOLLO GUIDANCE AND NAVIGATION
BURN BABY BURN
(MASTER IGNITION ROUTINE)
DRAWN A.C.WILLIAMS 5JUNE69
PROGR C. Schulenberg 6 AUG 69
ANALYST
DOCMR W.C. Dapprich 6 AUG 69
APPR'D Allen Y. Grant 6 AUG 69
LUMINARY 1C
DOCUMENT NO. FC-3840
REV 2
SHEET 2 OF 25



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C.WILLIAMS	5JUNE69	BURN BABY BURN (MASTER IGNITION ROUTINE)
PRGMR C. Schulenberg	6 AUG 69	
ANALST		LUMINARY 1C
DOCMR M C Dunford	6 AUG 69	DOCUMENT NO. FC-3840
APPR'D		REV 2 SHEET 8 OF 25



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C.WILLIAMS	5JUNE69	BURN BABY BURN (MASTER IGNITION ROUTINE)	
PRGMR C. Schulenberg	6 AUG 69	LUMINARY 1C	DOCUMENT NO. FC-3840
ANALST			
DOCMR MC Dagnit	6 AUG 69	REV 2	SHEET 4 OF 25
APPR'D Alex Hoy Lawrence	6 AUG 69		



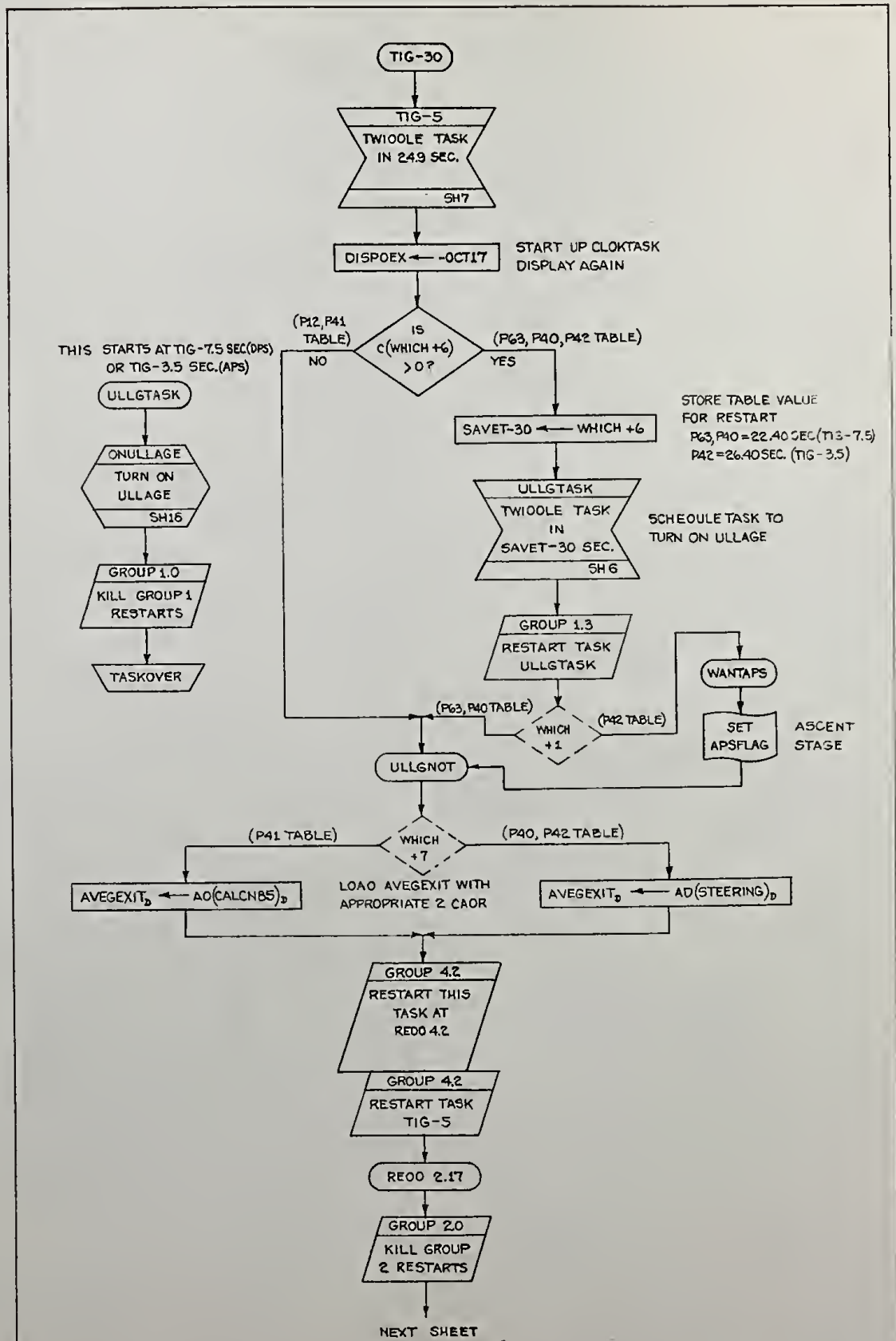
A.C.WILLIAMS 6-20-68

BURN BABY BURN
(MASTER IGNITION ROUTINE)

LUMINARY 1C

FC-3840

2 5 25

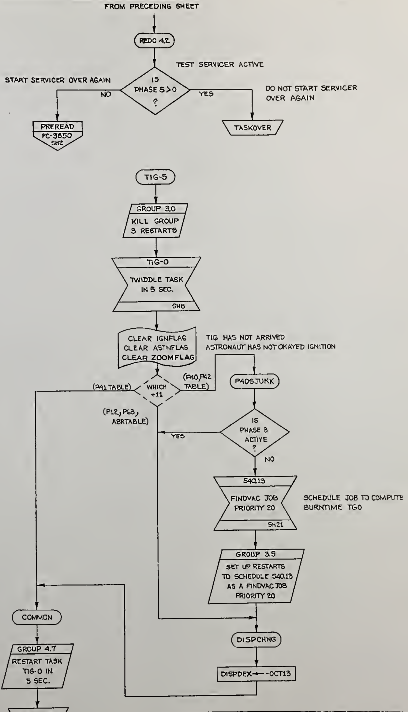


A.C. WILLIAMS 6-21-68

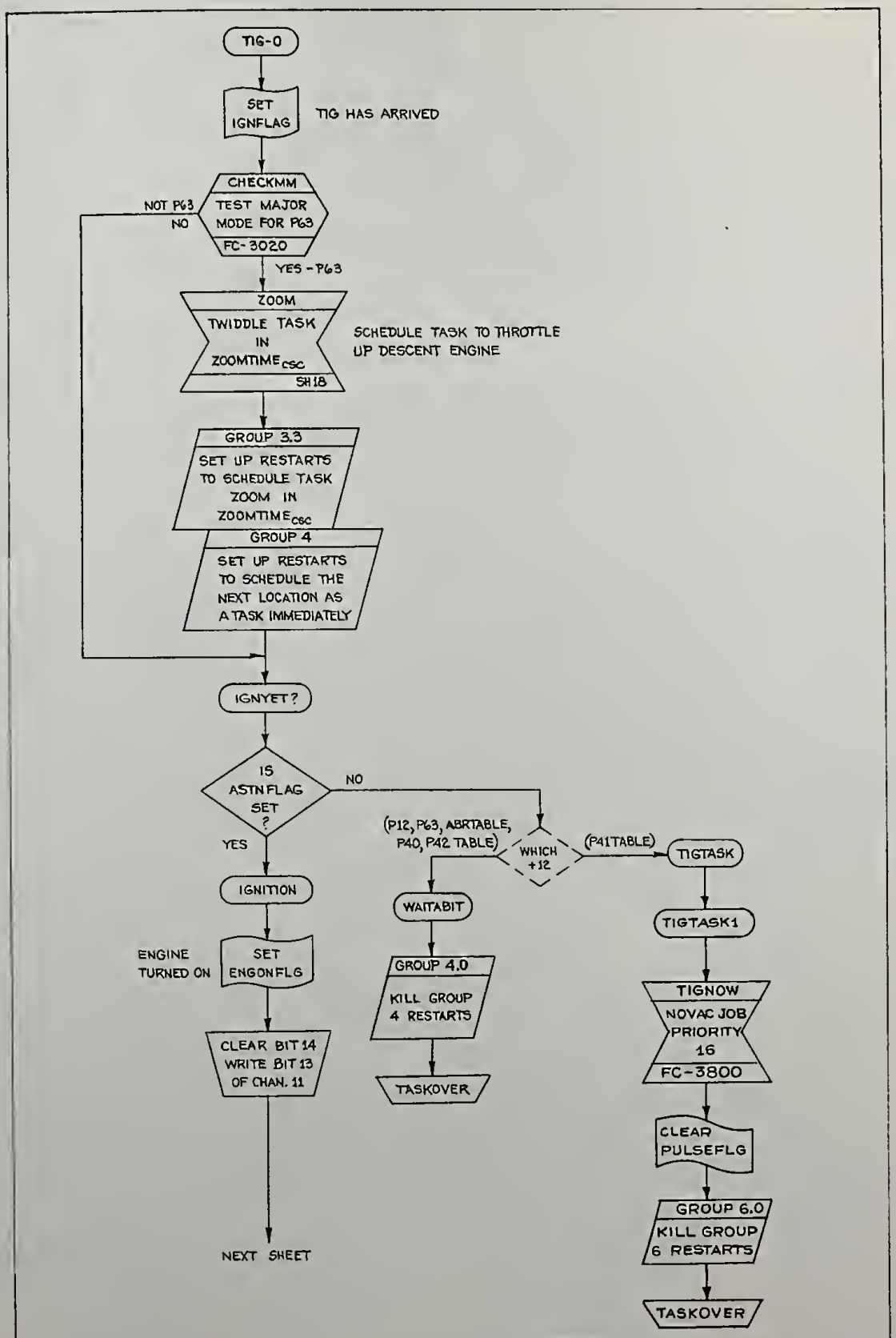
BURN BABY BURN
(MASTER IGNITION ROUTINE)

LUMINARY 1C

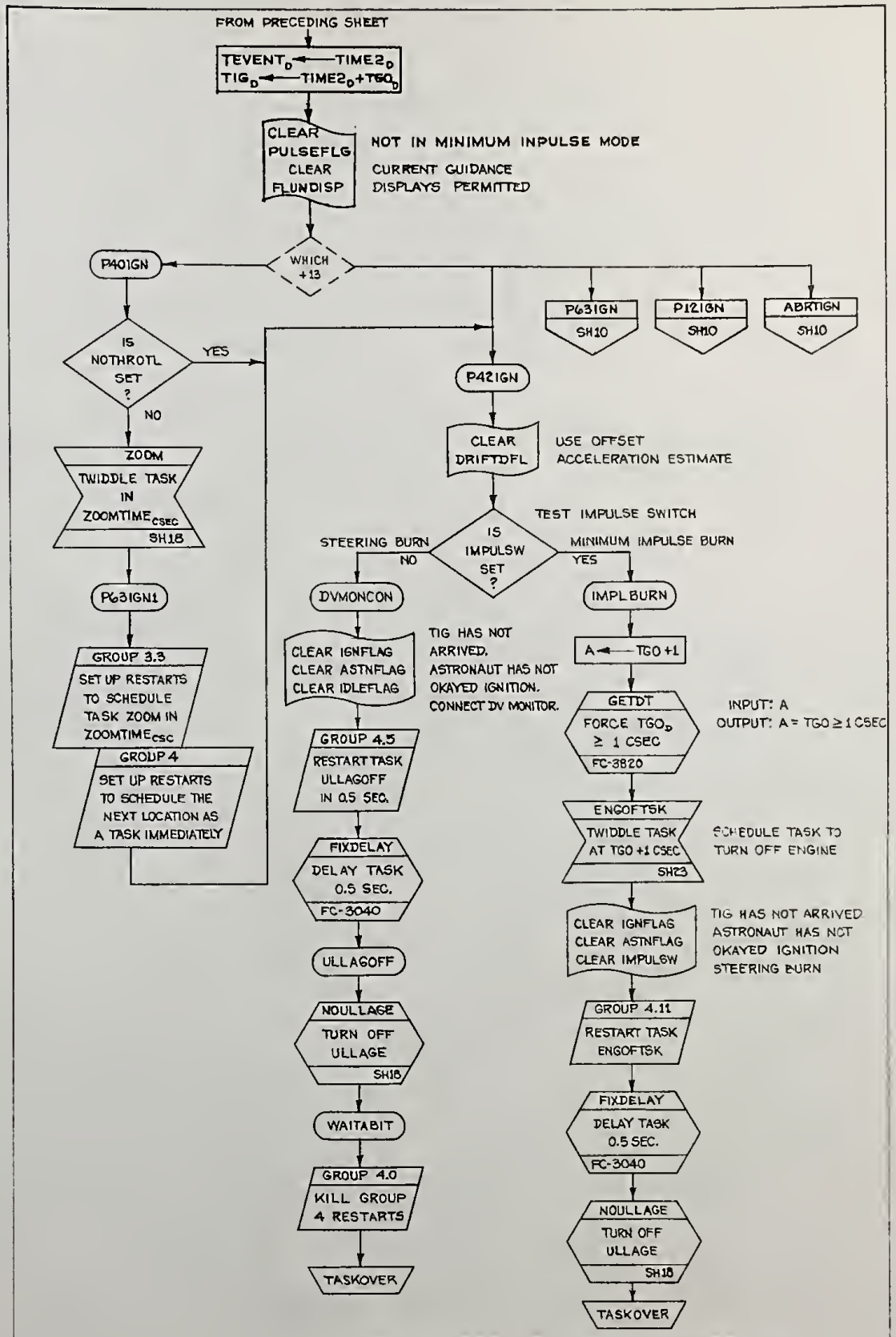
FC-3840



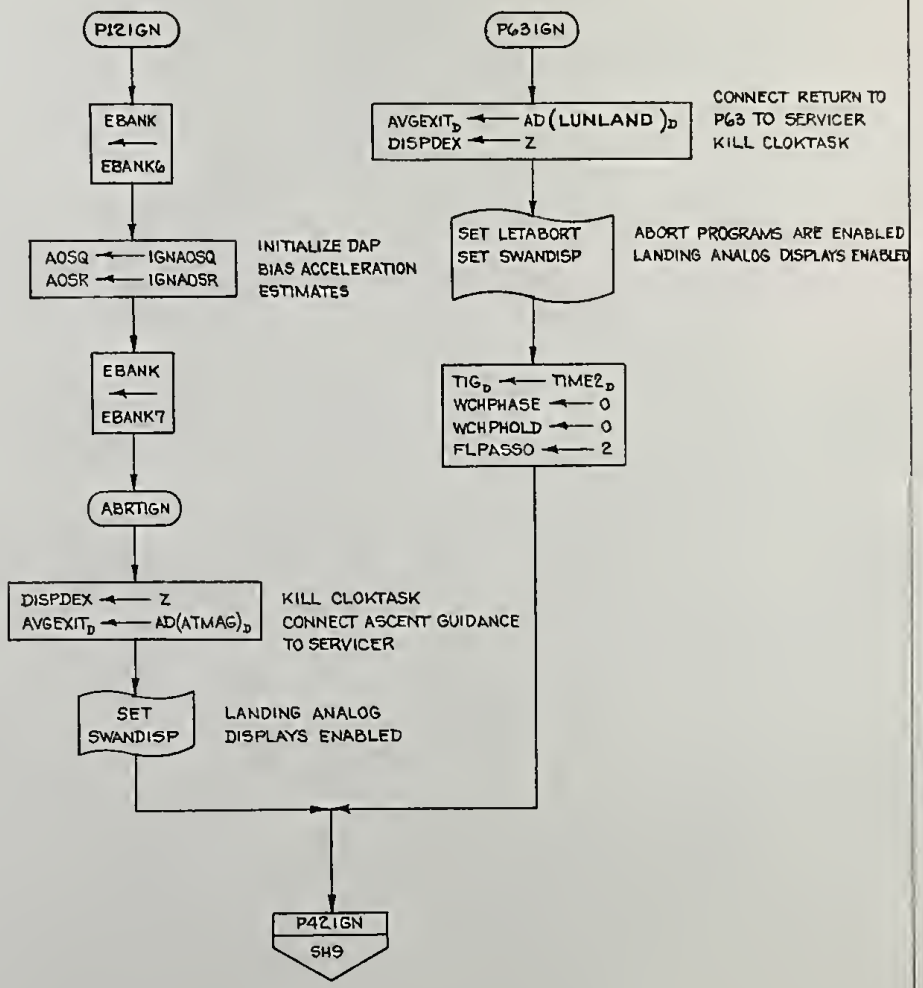
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C WILLIAMS 6JUNE69	BURN BABY BURN (MASTER IGNITION ROUTINE)
PRGMR C Schulenberg 6AUG69	LUMINARY 1C
ANALYST	DOCUMENT NO. FC-3840
DOCMR MC Dasfeld 6AUG69	
APPR'D [illegible] 6AUG69	REV 2 SH 7 OF 25



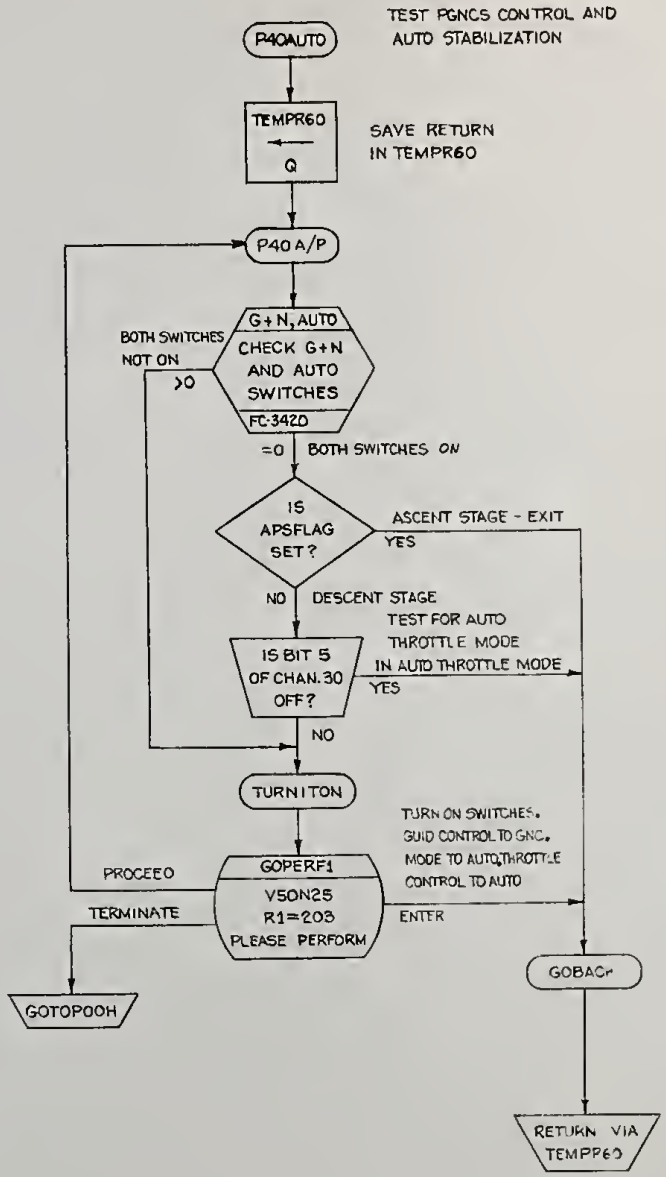
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C.WILLIAMS	9JUNE69	BURN BABY BURN (MASTER IGNITION ROUTINE)
PROGR C Schulenberg	6 AUG 69	
ANALST		LUMINARY 1C / DOCUMENT NO. FC-3840
DOCMR Mc Dayton	6 AUG 69	
APPRD		REV 2



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C.WILLIAMS	10JUN69	BURN BABY BURN (MASTER IGNITION ROUTINE)	
PRGMR C Schulenberg	6AUG69	LUMINARY 1C	DOCUMENT NO FC-3840
ANALST			
DOCMR MC Dagbert	6AUG69	REV 2	SHEET 9 OF 25
APPR'D			



MIT INSTRUMENTATION LAB CAMBRIDGE MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C. WILLIAMS	10JUN69	BURN BABY BURN (MASTER IGNITION ROUTINE)	
PROGMR C. Schulenberg	6AUG69	LUMINARY 1C	DOCUMENT NO. FC-384)
ANALST			
APPROVED	6AUG69	REV 2	SHEET 10 OF 25



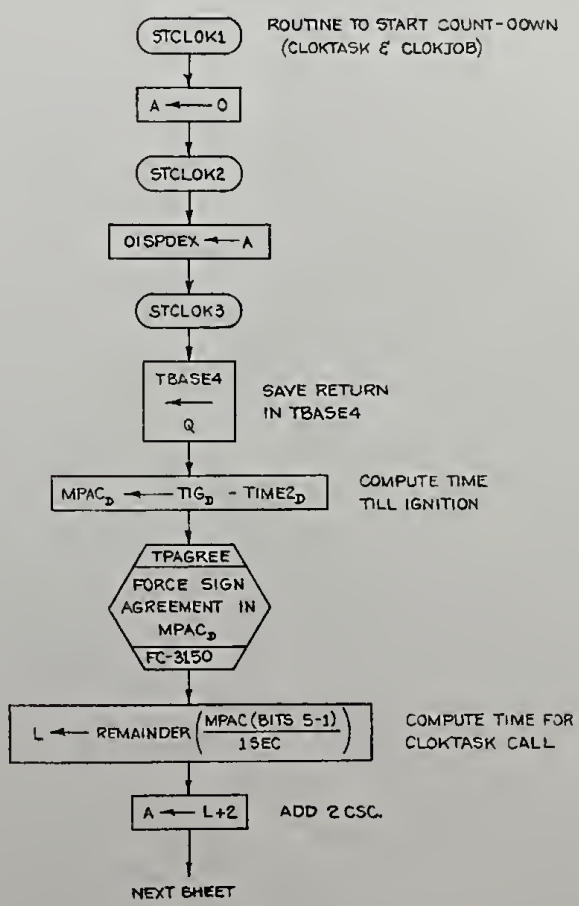
BURN BABY BURN
(MASTER IGNITION ROUTINE)

A.C. WILLIAMS 6-25-68

LUMINARY 1C

FC-3840

2 11 25



A.C. WILLIAMS 6-27-68.
4 Sept 68
11 Oct 68
7-29-68
John L. Moss 24 Oct 68

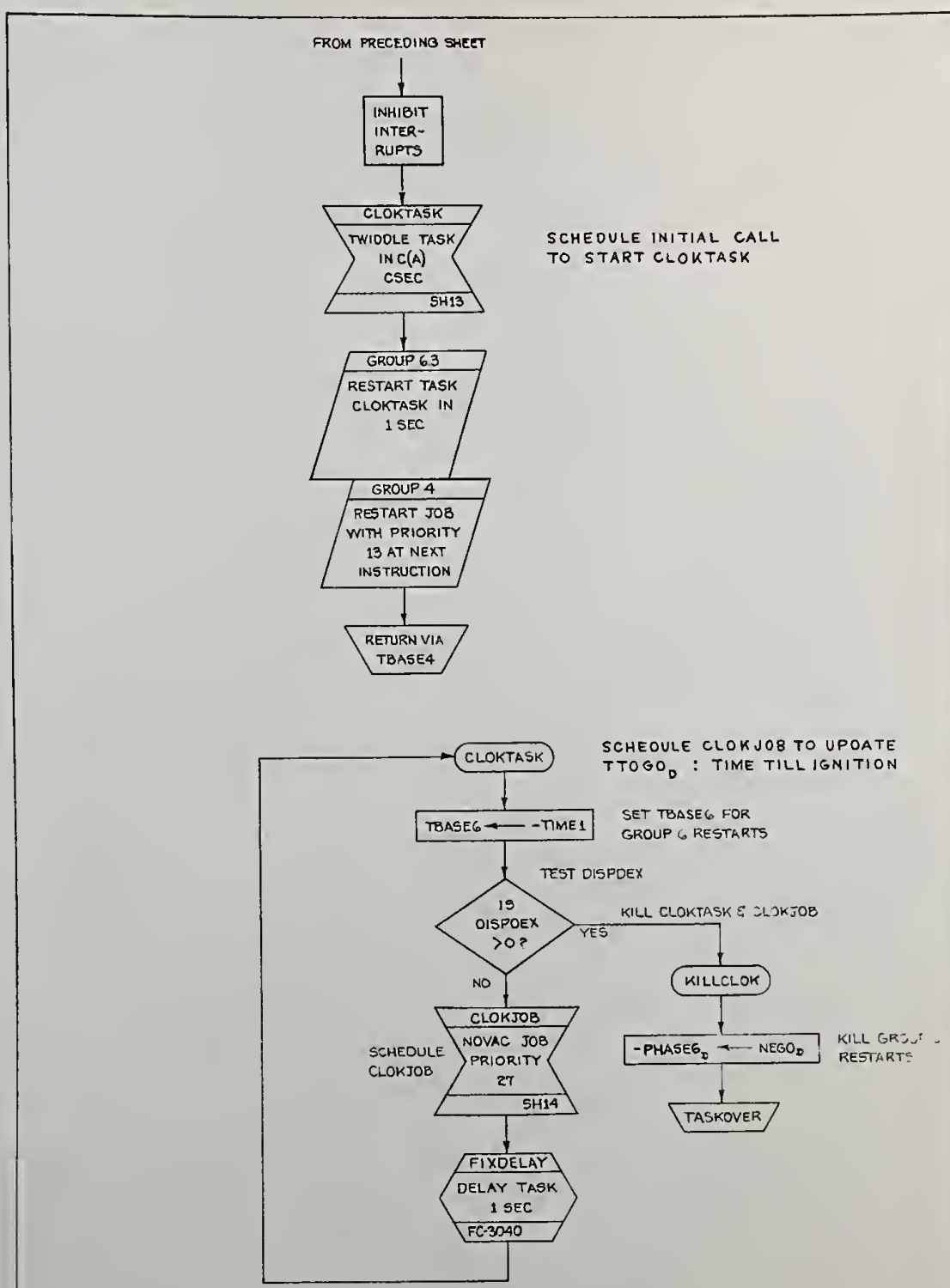
BURN BABY BURN
(MASTER IGNITION ROUTINE)

LUMINARY 1C

FC-3840

2

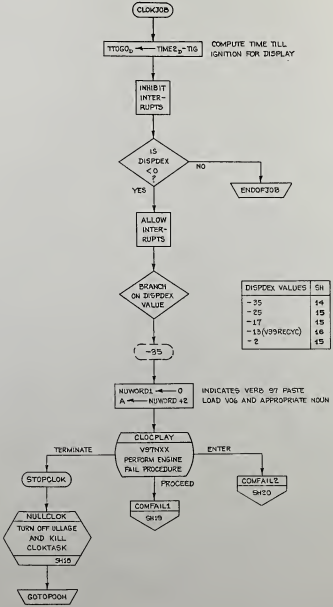
12 25



BURN BABY BURN
(MASTER IGNITION ROUTINE)

A.C.WILLIAMS 6-27-68
LUMINARY 1C
FC-3840

2 13 25



DISPDEX VALUES	SH
-35	14
-25	15
-17	15
-13(V99RECYC)	16
-2	15

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.

APOLLO GUIDANCE AND NAVIGATION

BURN BABY BURN (MASTER IGNITION ROUTINE)

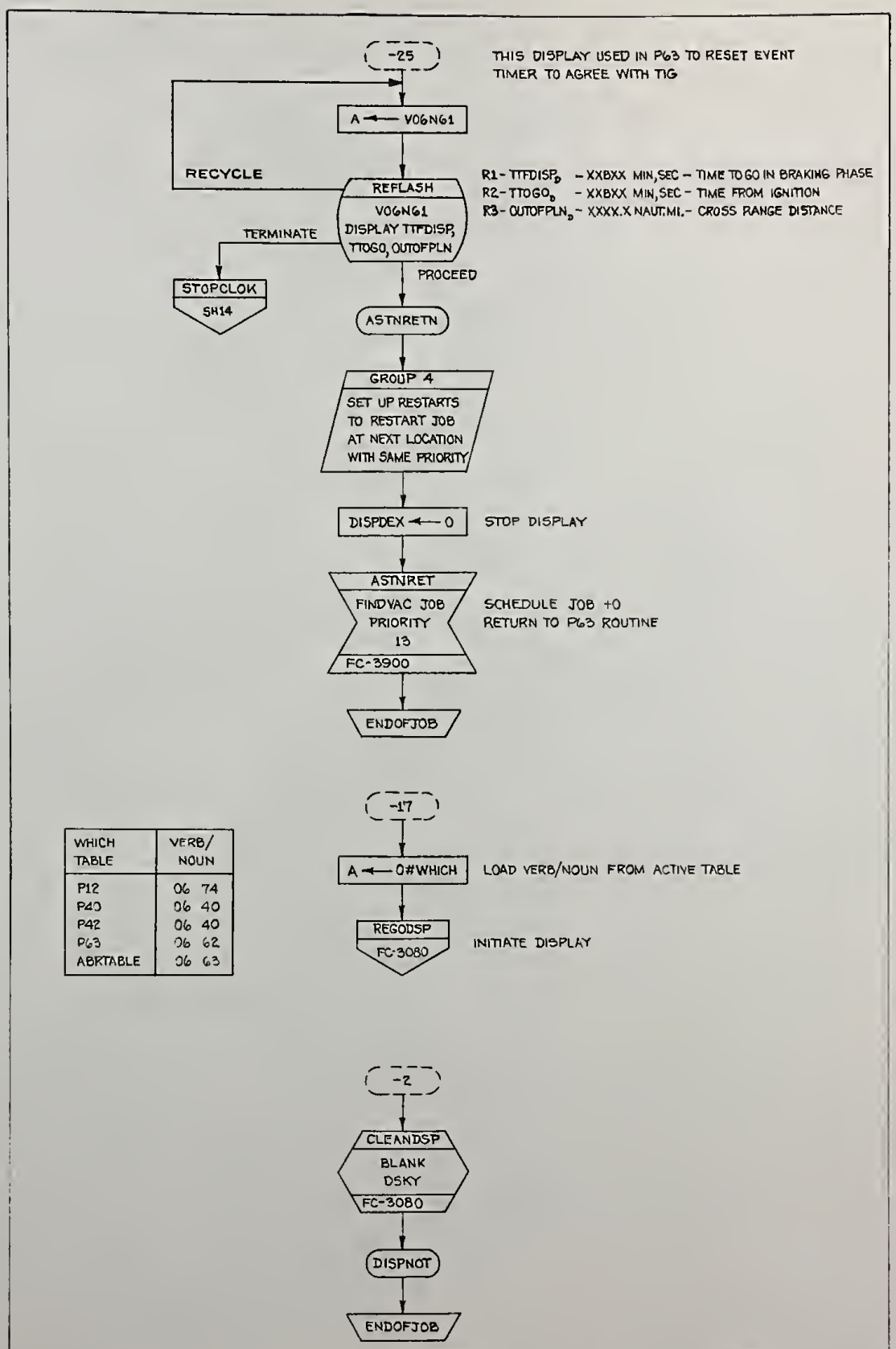
DRAWN A.C.WILLIAMS 11JUN69
PRGMR C. Schulenberg 6AUG69
ANALYST
DOCMR 6AUG69
APPR'D

LUMINARY 1C

DOCUMENT NO. FC-3840

REV 2

SHEET 14 OF 25



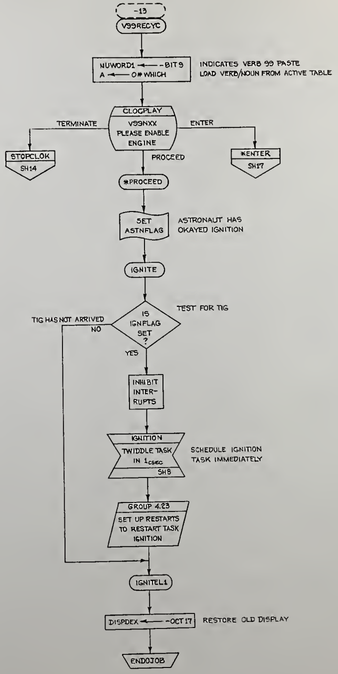
WHICH TABLE	VERB/ NOUN
P12	06 74
P40	06 40
P42	06 40
P63	06 62
ABRTABLE	06 63

MIT
INSTRUMENTATION LAB
CAMBRIDGE, MASS.

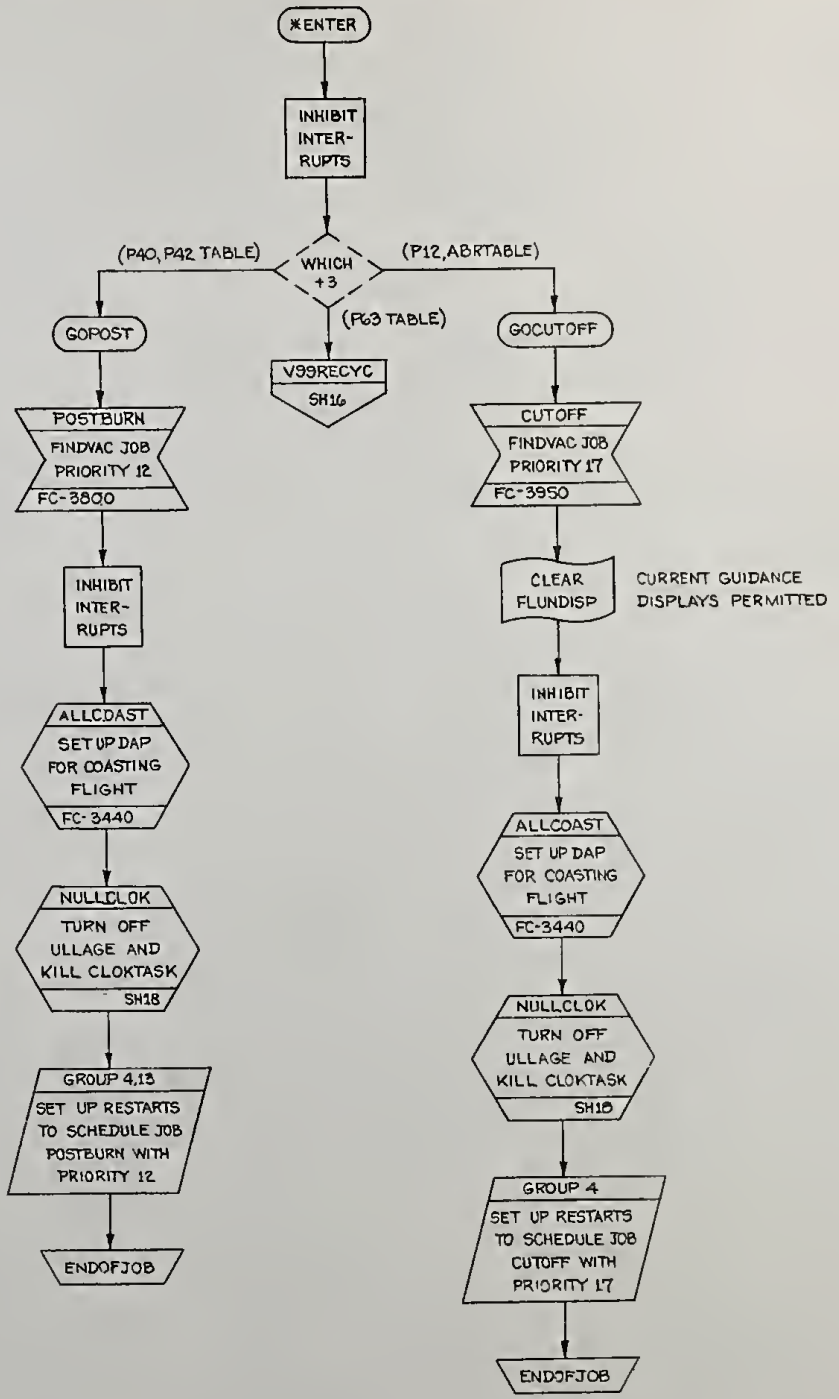
APOLLO
GUIDANCE AND NAVIGATION

DRAWN A.C.WILLIAMS 11JUN69
PROGR C. Schulenberg 6 AUG 69
ANALST
DOCMR W.C. Duffith 6 AUG 69
APPRD Alexander Kossiakoff 6 AUG 69

BURN BABY BURN
(MASTER IGNITION ROUTINE)
LUMINARY 1C
DOCUMENT FC-384
REV 2
UNIT 18 25



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C. WILLIAMS 12JUN69	BURN BABY BURN (MASTER IGNITION ROUTINE)
CHECKED C. Schulenberg 6AUG69	LUMINARY 1C — DOCUMENT NO FC-3840
DOC MR [illegible] 6AUG69	
APPR'D [illegible] 6AUG69	REV 2 — SHEET 16 OF 25



MIT
INSTRUMENTATION LAB
CAMBRIDGE, MASS.

DRAWN A.C.WILLIAMS 12JUN69
C. Schulenberg 6 AUG 69
ANALYST
PROGRAMMER W.C. Daggett 6 AUG 69
APPROVED Ascension Scott 6 AUG 69

APOLLO GUIDANCE AND NAVIGATION

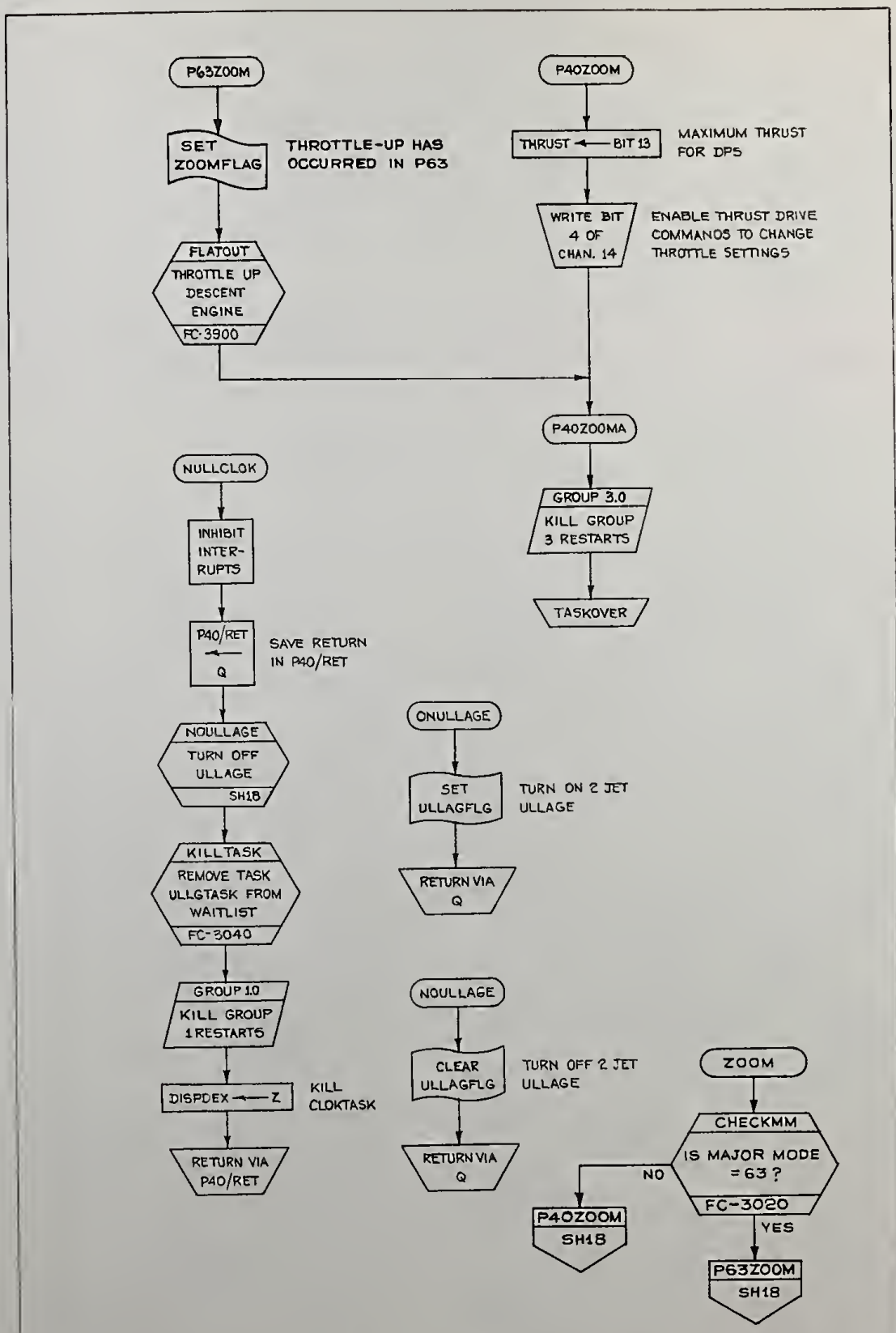
BURN BABY BURN
(MASTER IGNITION ROUTINE)

LUMINARY 1C

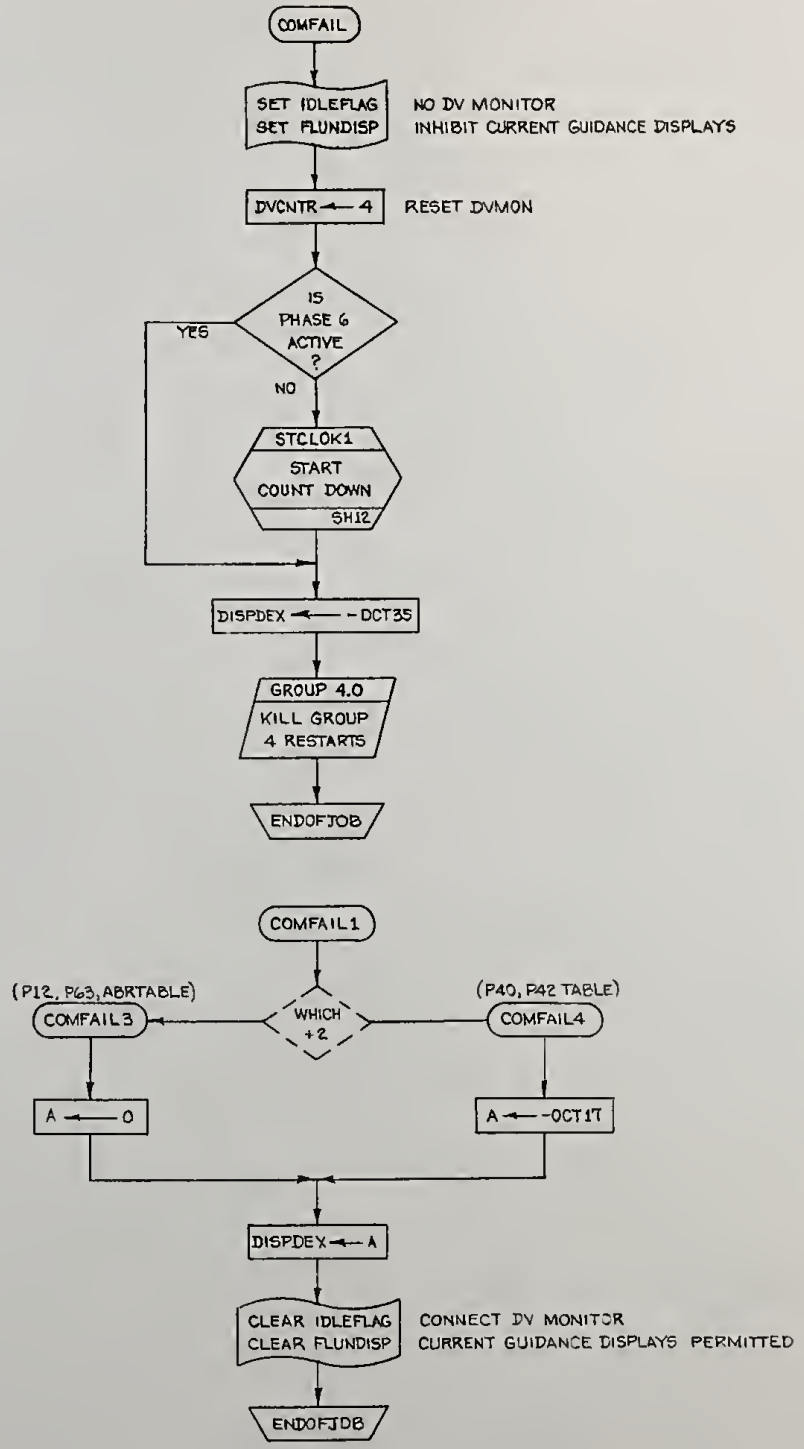
DOCUMENT NO. FC-3840

REV 2

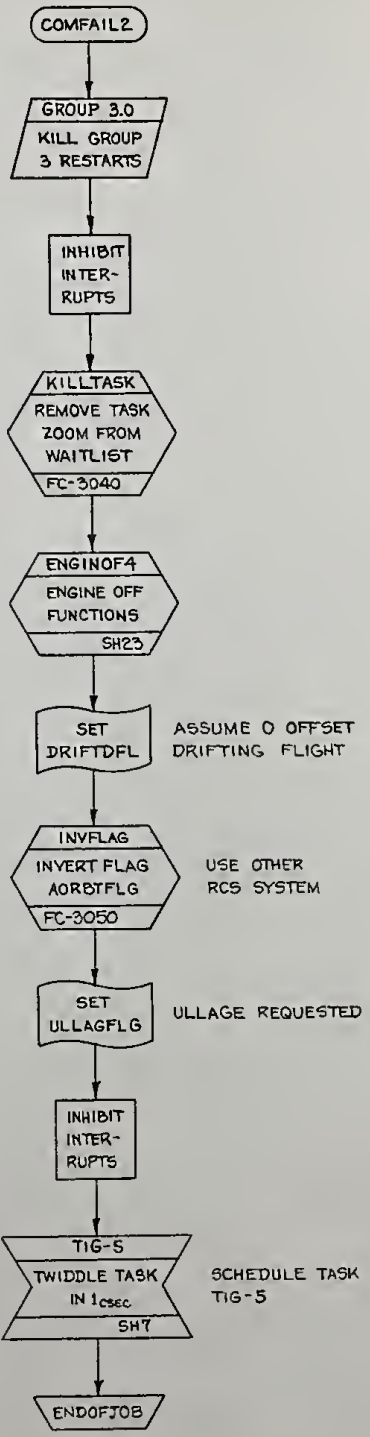
SHEET 17 25



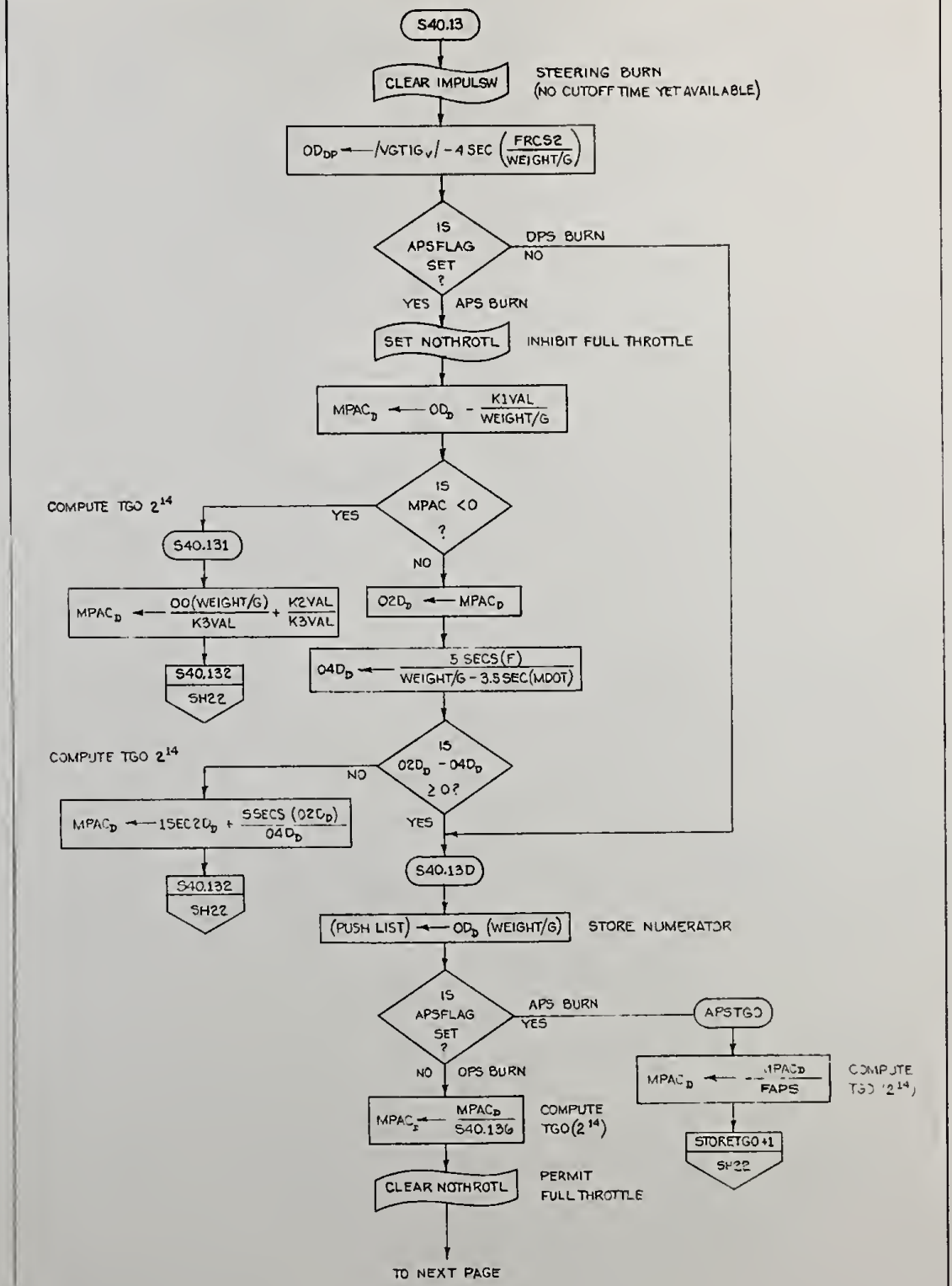
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	A.C.WILLIAMS	12JUN69	BURN BABY BURN (MASTER IGNITION ROUTINE)
PRGMR	C. Schulenberg	6 AUG 69	
ANALST			LUMINARY 1C
DSKMR	[illegible]	6 AUG 69	DOCUMENT NO. FC-3840
APPR'D	[illegible]	AUG 69	REV 2 SHEET 18 OF 25



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN A.C WILLIAMS	13 JUN 69	BURN BABY BURN (MASTER IGNITION ROUTINE)	
PROGMR C. Schulenberg	6 AUG 69	LUMINARY 1C	DOCUMENT NO. FC-3840
ANALST		REV 2	SHEET 19 OF 25
DOLMR W C Dayton	6 AUG 69		
APPR'D Allen M. Svant	6 Aug 69		



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN A.C.WILLIAMS 13JUN69	BURN BABY BURN (MASTER IGNITION ROUTINE
PROGR C. Schuldenberg 6 AUG 69	LUMINARY 1C
ANALYST	DOCUMENT NO. FC-384
DOCMR W.O. Bradford 6 AUG 69	REV 2
APPR'D	SHEET 20 OF 25



BURN BABY BURN
(MASTER IGNITION ROUTINE)

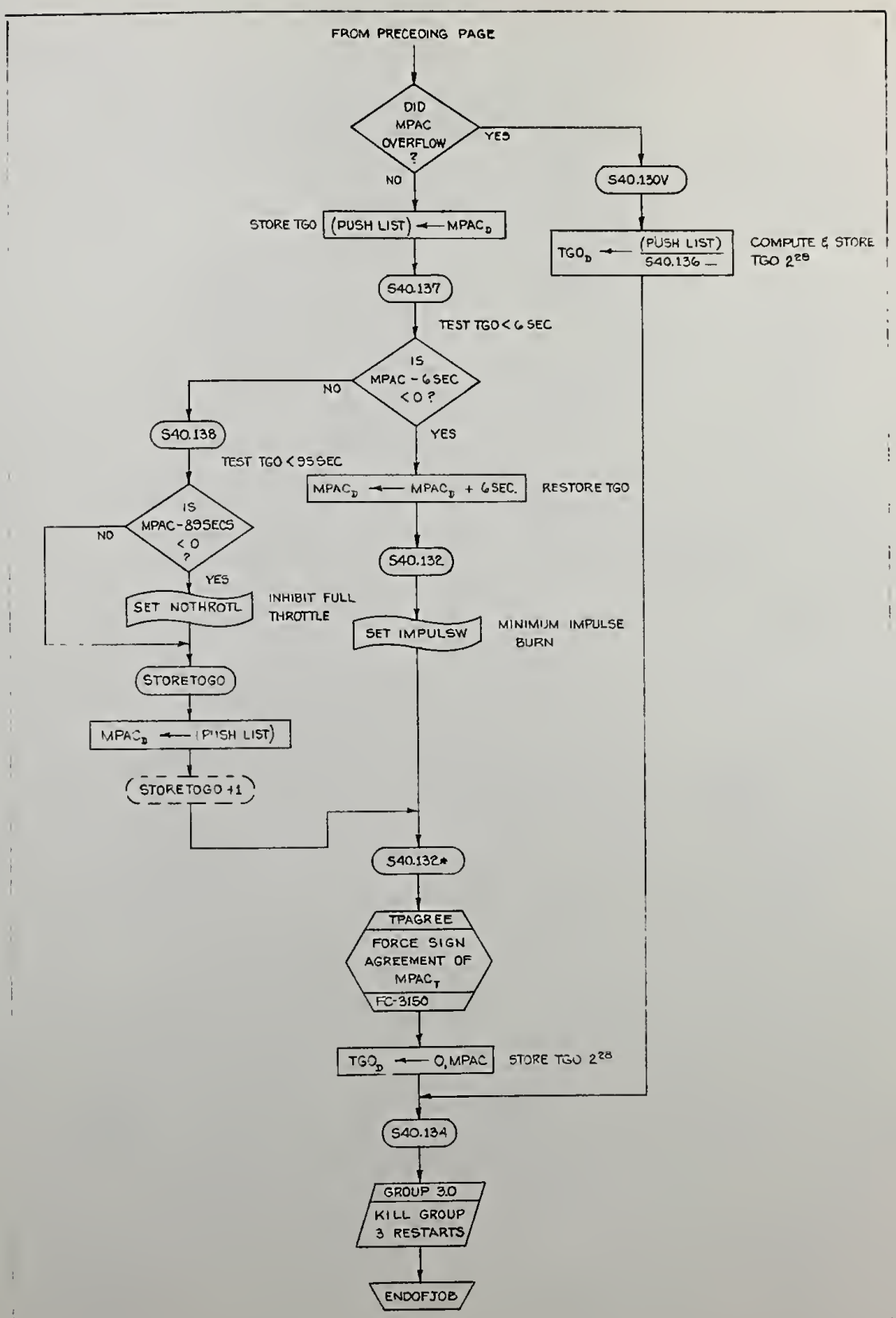
A.C.WILLIAMS 6-28-68
[illegible] [illegible]68
[illegible] 10 Jan 69
W. C. Taylor 1-29-68
John A. Moss 24 JAN 69

LUMINARY 1C

FC-3840

2

21 25

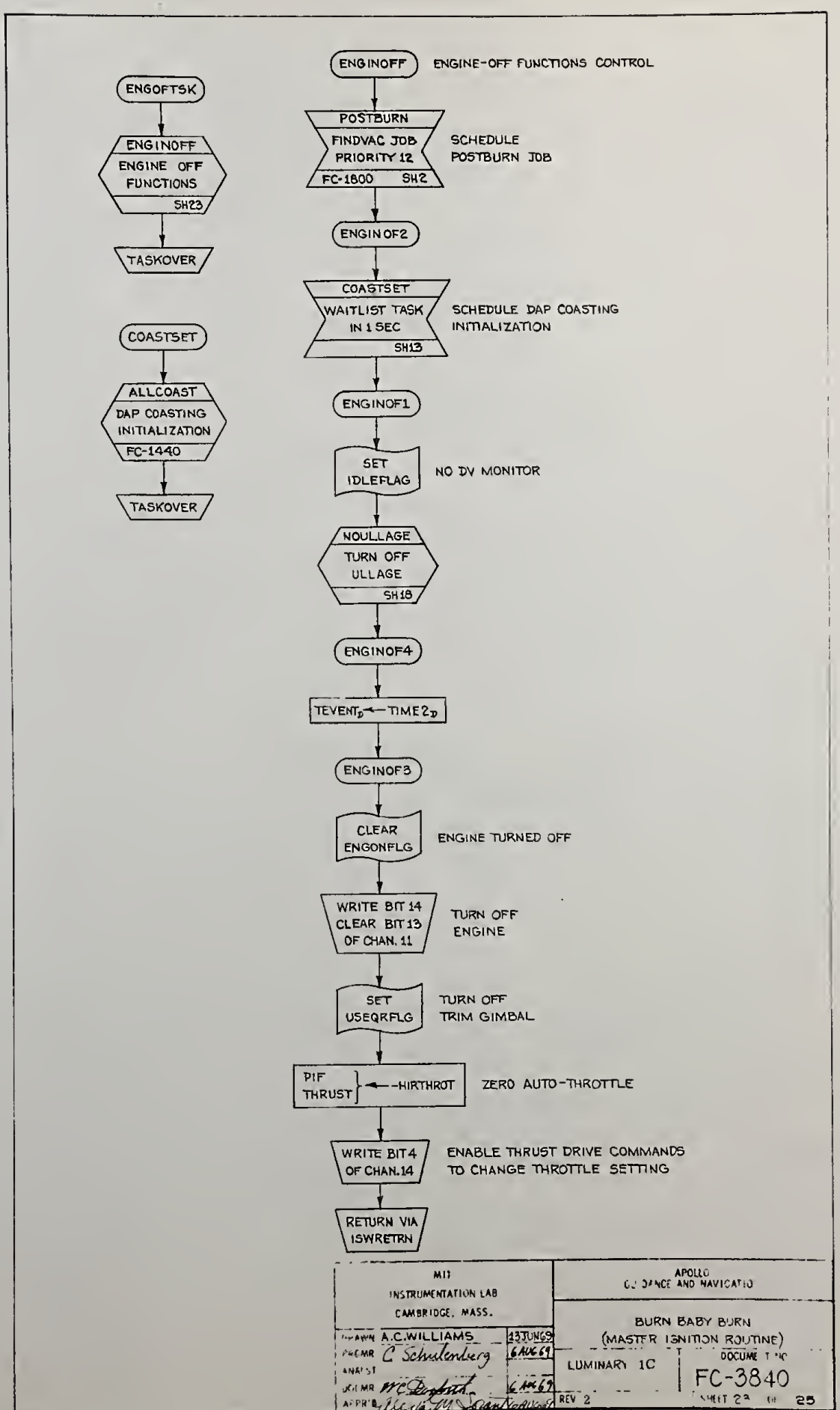


BURN BABY BURN
(MASTER IGNITION ROUTINE

A.C.WILLIAMS 7-1-68
LUMINARY 1C
FC-3840

2

22 25


ENGOFTSK
ENGINOFF
ENGINE OFF FUNCTIONS
SH23
TASKOVER
COASTSET
ALLCOAST
DAP COASTING INITIALIZATION
FC-1440
TASKOVER
ENGINOFF
ENGINE-OFF FUNCTIONS CONTROL
POSTBURN
FINDVAC JOB PRIORITY 12
FC-1800 SH2
SCHEDULE POSTBURN JOB
ENGINOF2
COASTSET
WAITLIST TASK IN 1 SEC
SH13
SCHEDULE DAP COASTING INITIALIZATION
ENGINOF1
SET IDLEFLAG
NO DV MONITOR
NOULLAGE
TURN OFF ULLAGE
SH18
ENGINOF4
TEVENT_D ← TIME2_D
ENGINOF3
CLEAR ENGONFLG
ENGINE TURNED OFF
WRITE BIT 14 CLEAR BIT 13 OF CHAN. 11
TURN OFF ENGINE
SET USEQRFLG
TURN OFF TRIM GIMBAL
PIF THRUST ← -HIRTHROT
ZERO AUTO-THROTTLE
WRITE BIT4 OF CHAN.14
ENABLE THRUST DRIVE COMMANDS TO CHANGE THROTTLE SETTING
RETURN VIA ISWRETRN
MIT
INSTRUMENTATION LAB
CAMBRIDGE, MASS.
APOLLO
GUIDANCE AND NAVIGATION
BURN BABY BURN
(MASTER IGNITION ROUTINE)
LUMINARY 1C
DOCUMENT NO
FC-3840
REV 2
SHEET 23 OF 25
DRAWN A.C.WILLIAMS 13JUN69
CHECKED C Schulenberg 6AUG69
ANALYST
PROGRAMMER 6 AUG 69
APPROVED

SUBROUTINES CALLED WHICH ARE FLOWED ON OTHER FLOW CHARTS

SUBROUTINE NAME	FLOW CHART	DESCRIPTION	WHERE CALLED
ALLCOAST	FC-3440	SET UP DAP FOR COASTING FLIGHT	SH. 17,23
CHECKMM	FC-3020	TEST MAJOR MODE	SH. 4,8
CLEANDSP	FC-3080	BLANK DSKY	SH. 5,15
CSMPREC	FC-3350	EXTRAPOLATE CSM STATE VECTOR	SH. 3
FIXDELAY	FC-3040	DELAY ACTIVE TASK	SH. 9,13
FLATOUT	FC-3900	THROTTLE UP DESCENT ENGINE	SH. 18
G&N,AUTO	FC-3420	CHECK G&N AND AUTO SWITCHES	SH. 11
INVFLAG	FC-3050	INVERT INPUT FLAG BIT	SH. 20
KILLTASK	FC-3040	REMOVE TASK FROM WAITLIST	SH. 18,20
MIDTOAV1	FC-3350	INTEGRATE LM STATE VECTOR	SH. 3
MUNGRAV	FC-3850	COMPUTE LUNAR GRAVITATIONAL ACCELERATION	SH. 3
TPAGREE	FC-3150	FORCE SIGN AGREEMENT IN $MPAC_T$	SH. 12,22

FLAGS

NAME	MEANING WHEN SET	MEANING WHEN CLEAR	WHERE SET	WHERE CLEARED	WHERE TESTED
APSFLAG FL. 10, BIT13	ASCENT STAGE	DESCENT STAGE			SH. 11
ASTNFLAG FL. 7, BIT12	ASTRONAUT HAS OKAYED IGNITION	ASTRONAUT HAS NOT OKAYED IGNITION	SH. 6,16	SH. 7,9	SH. 8
DRIFTDFL FL. 13, BIT8	T3RUPT CALLS GYRO COMPENSATION	T3RUPT DOES NO GYRO COMPENSATION	SH. 20	SH. 9	
ENGONFLG FL. 5, BIT7	ENGINE TURNED ON	ENGINE TURNED OFF	SH. 8	SH. 23	
FLUNDISP FL. 8, BIT10	CURRENT GUIDANCE DISPLAYS INHIBITED	CURRENT GUIDANCE DISPLAYS PERMITTED	SH. 19	SH. 9, 17, 19	
IDLEFLAG FL. 7, BIT7	NO DV MONITOR	CONNECT DV MONITOR	SH. 19	SH. 9, 19	
IGNFLAG FL. 7, BIT13	TIG HAS ARRIVED	TIG HAS NOT ARRIVED	SH. 8	SH. 7, 9	SH. 16
IMPULSW FL. 2, BIT9	MINIMUM IMPULSE BURN	STEERING BURN	SH. 22	SH. 9, 21	SH. 9
MUNFLAG FL. 6, BIT8	SERVICER CALLS MUNRVG	SERVICER CALLS CALCRVG			SH. 3
NOTHROTL FL. 5, BIT12	INHIBIT FULL THROTTLE	PERMIT FULL THROTTLE	SH. 21, 22	SH. 21	SH. 9
ULLAGFLG FL. 13, BIT6	ULLAGE REQUESTED BY MISSION PROGRAM	NO INTERNAL ULLAGE REQUEST	SH. 18, 20	SH. 18	
USEQRFLG FL. 13, BIT14	GIMBAL UNUSABLE. USE JETS ONLY	TRIM GIMBAL MAY BE USED	SH. 23		
LETABORT FL. 9, BIT9	ABORT PROGRAMS ARE ENABLED	ABORT PROGRAMS ARE NOT ENABLED	SH. 10		
PULSEFLG FL. 13, BIT15	MINIMUM IMPULSE COMMAND MODE	NOT IN MINIMUM IMPULSE COMMAND MODE		SH. 10	
SWANDISP FL. 7, BIT11	LANDING ANALOG DISPLAYS ENABLED	LANDING ANALOG DISPLAYS SUPPRESSED	SH. 10		

DISPLAYS

V06N40 V99N40	R1 - TTOGO - XXBXX MIN-SEC - TIME TO IGNITION/CUTOFF R2 - VGDISP - XXXX.X FT/SEC-VG R3 - DVTOTAL - XXXX.X FT/SEC - DELTA V	SH. 13

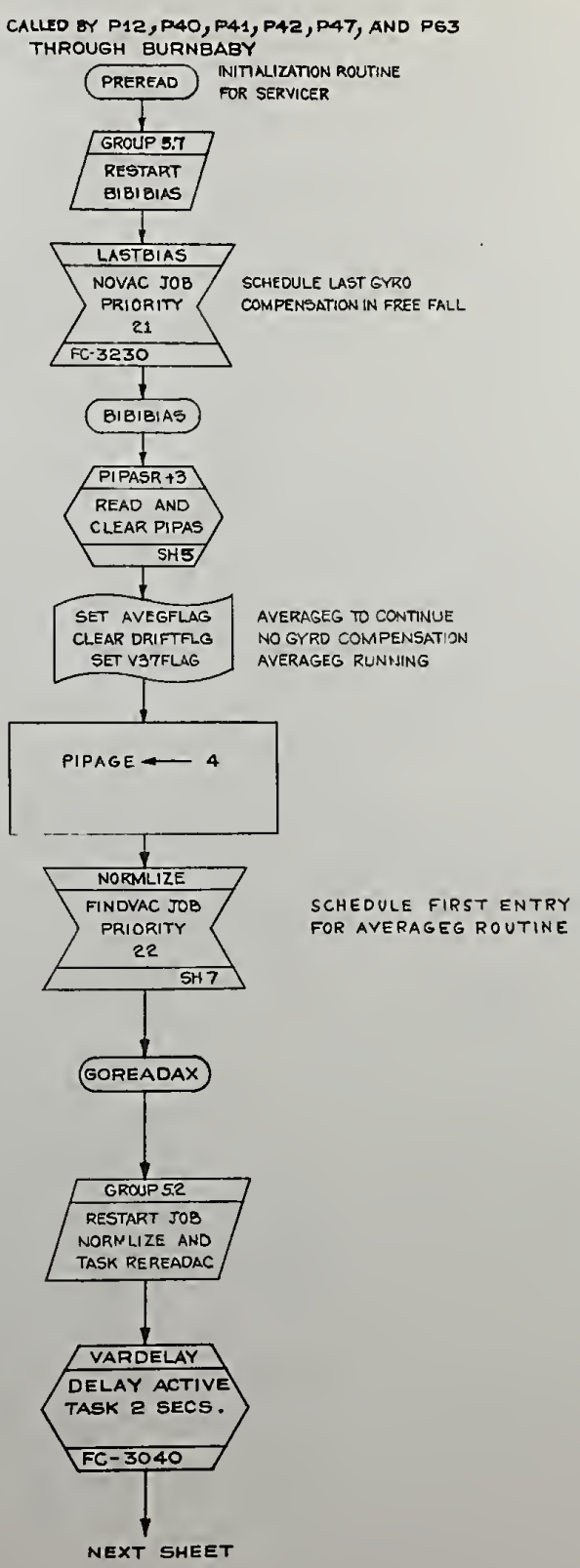
ERASABLE LOCATIONS USED

		UNITS	SCALING
TIG_D	TIME OF ENGINE IGNITION	CSEC	2^{28}
TGO_D	TIME FROM ENGINE CUT-OFF	CSEC	2^{28}
PIF THRUST	AUTO THROTTLE COMMAND REGISTERS	-	-

SERVICER

MAJOR SUBROUTINES ON THIS CHART

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN J. Goldstone	9/13/68	SERVICER	
PRGMR Bruce McCoy	9/16/68	LUMINARY 1C	DOCUMENT NO. FC-3850
ANALST			
DOCMR M C Dyke	9/16/69		
APPR'D Robert M Eyles	9-16-69	REV 2	SHEET 1 OF 20



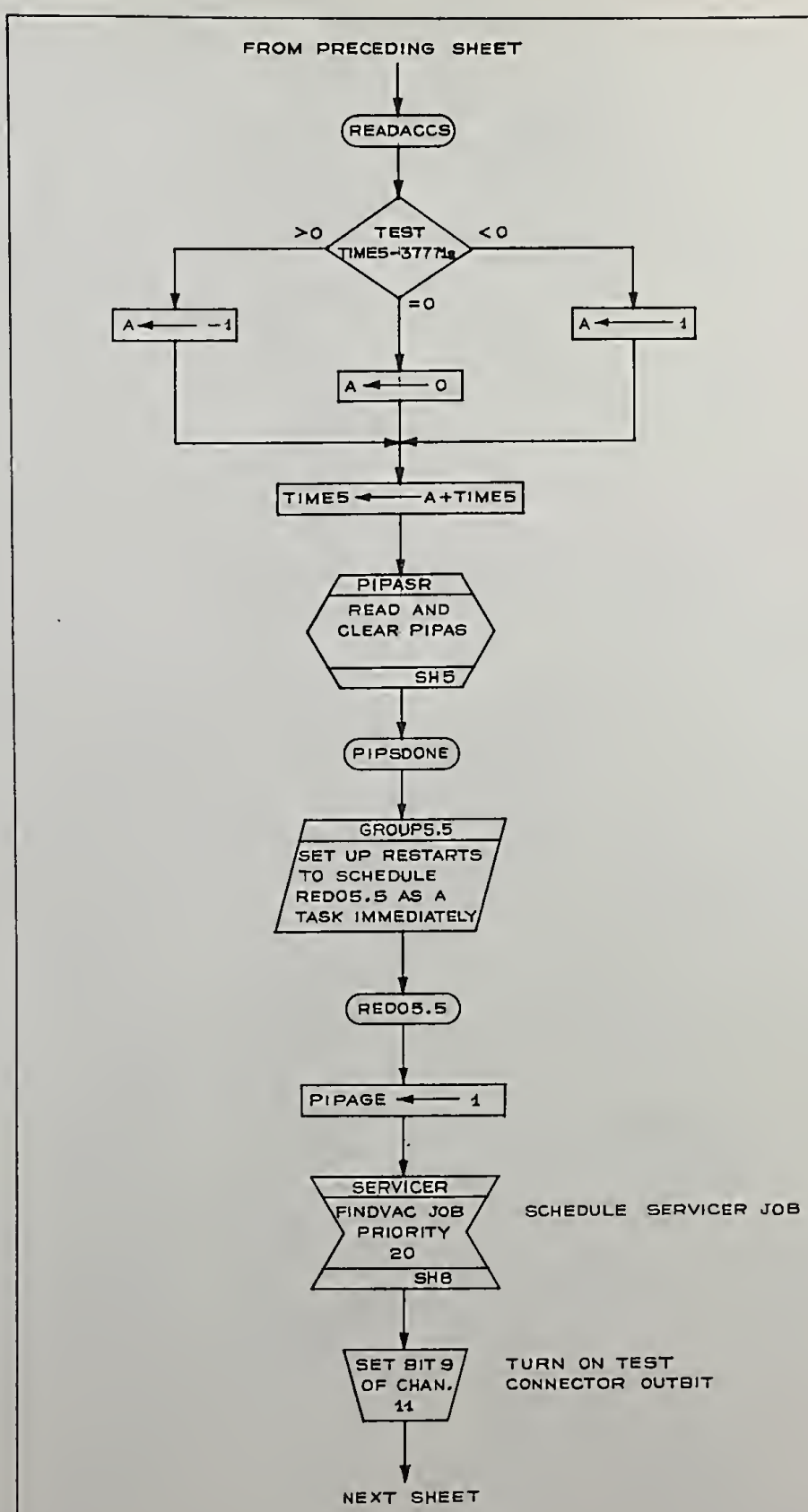
SERVICER

A.C WILLIAMS 6-11-68

LUMINARY 1C

FC-3850

2 20



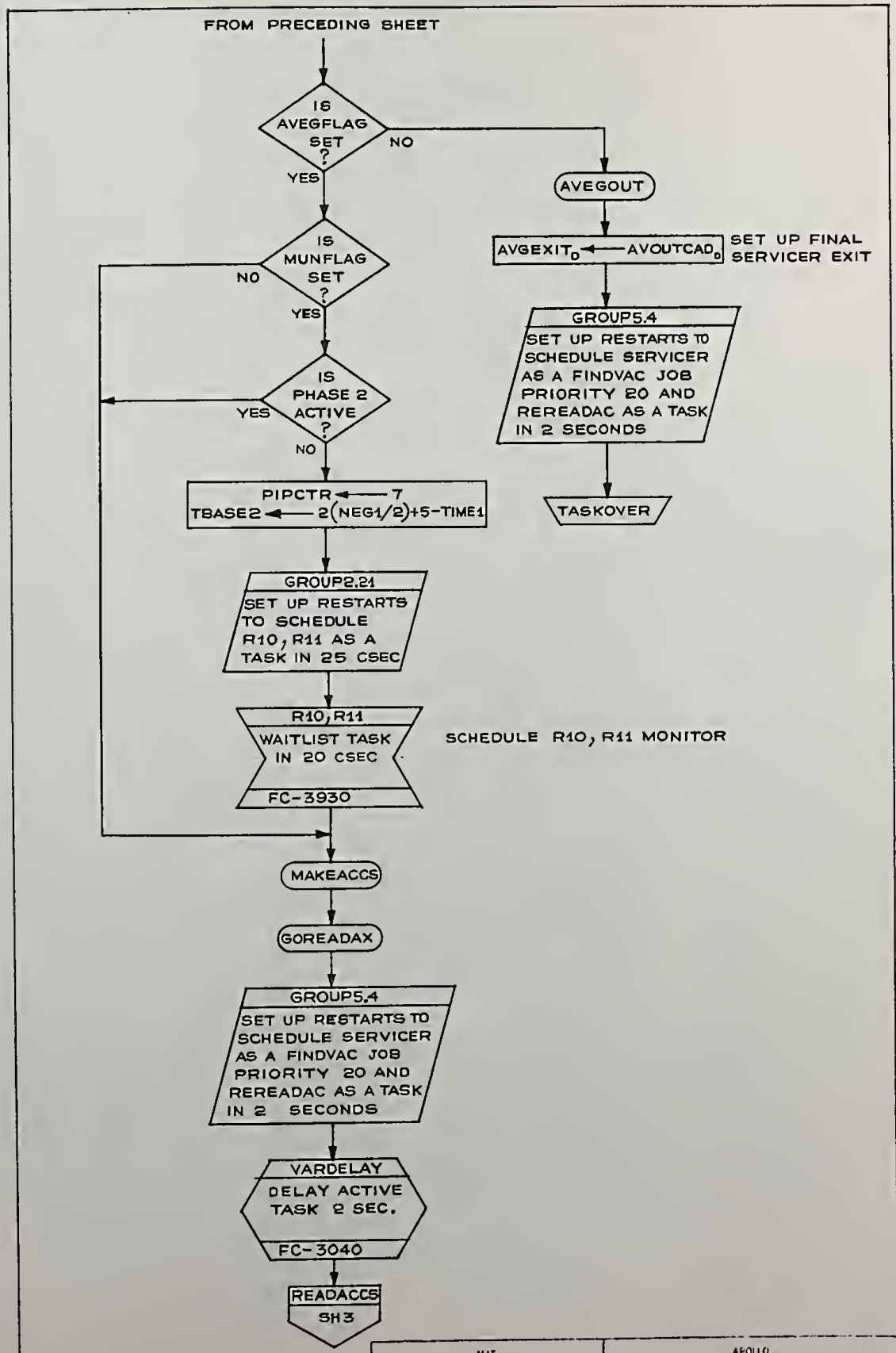
MIT
INSTRUMENTATION
CAMBRIDGE MASS.

SERVICER

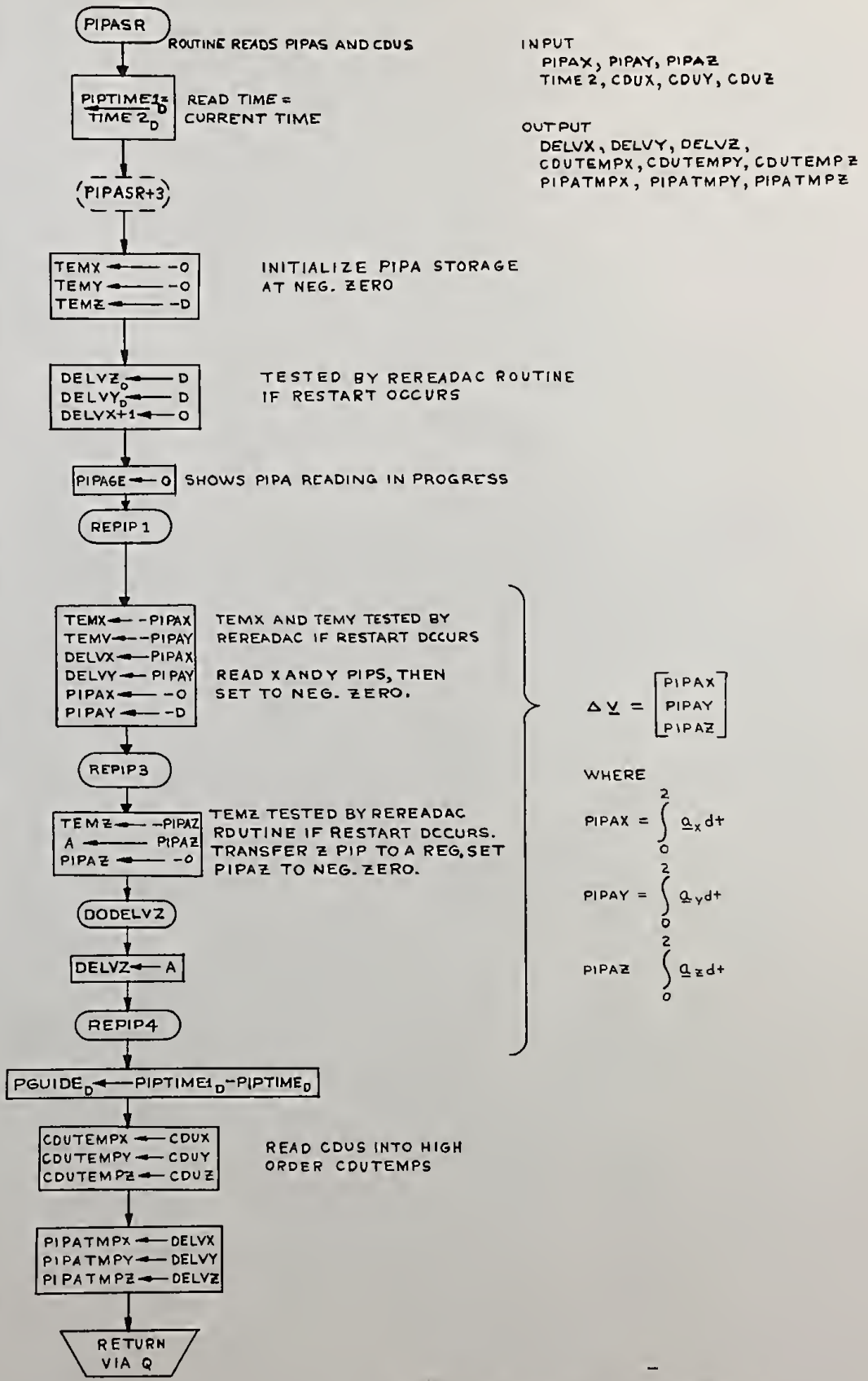
LUMINARY 1C

FC-3850

3 20



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN P.M. Distler	15 MAY 68	SERVICER
PROGR C. Schudenberg	13 AUG 68	LUMINARY 1C
ANALYST		DOCUMENT NO. FC-3850
DSR MR W.C. Dietrich	13 AUG 68	REV 1
APPR'D Hugh Blair-Smith		SHEET 4 OF 20



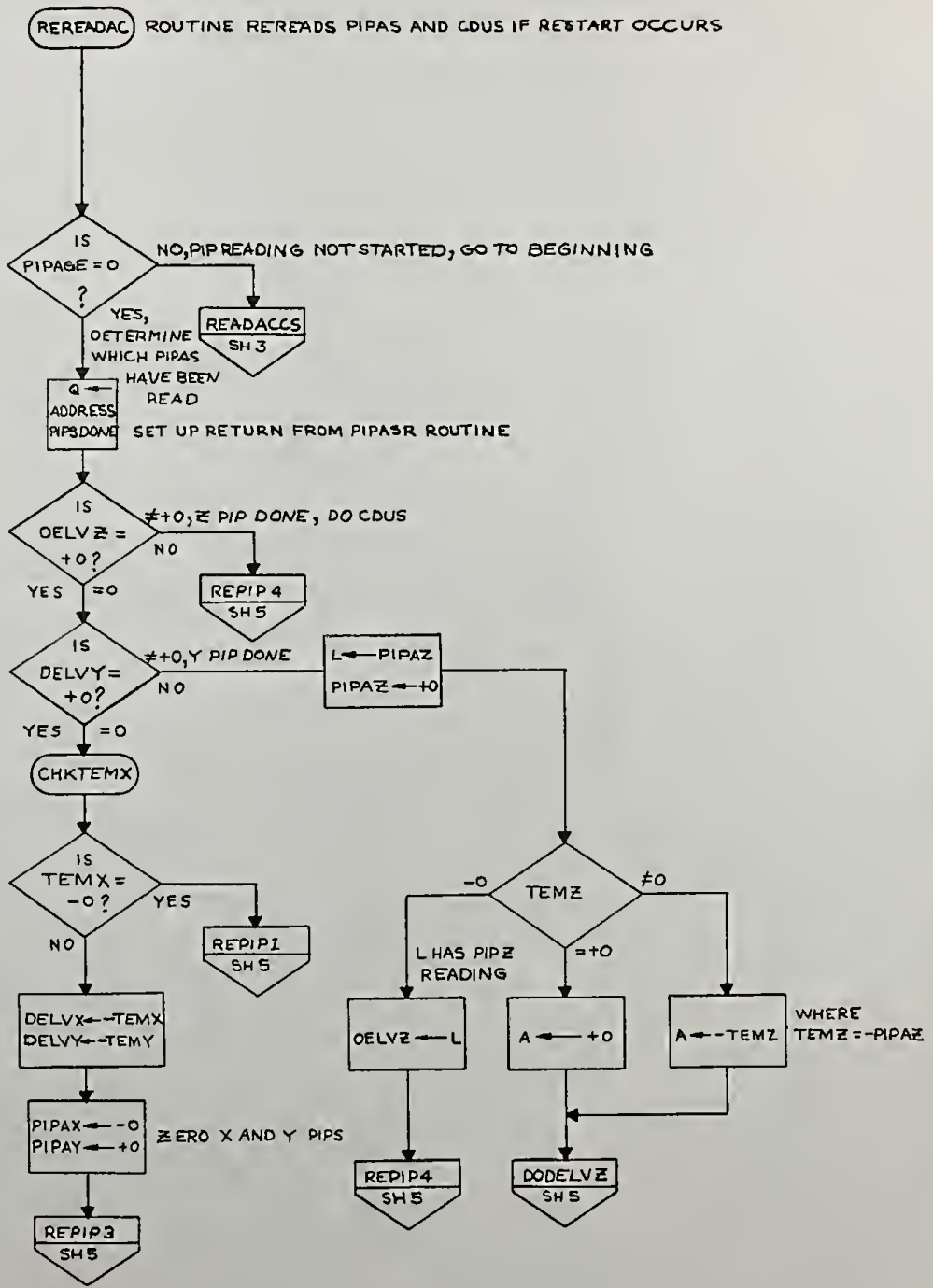
SERVICER

25JUL68

LUMINARY 1C

FC-3850

2 5 20



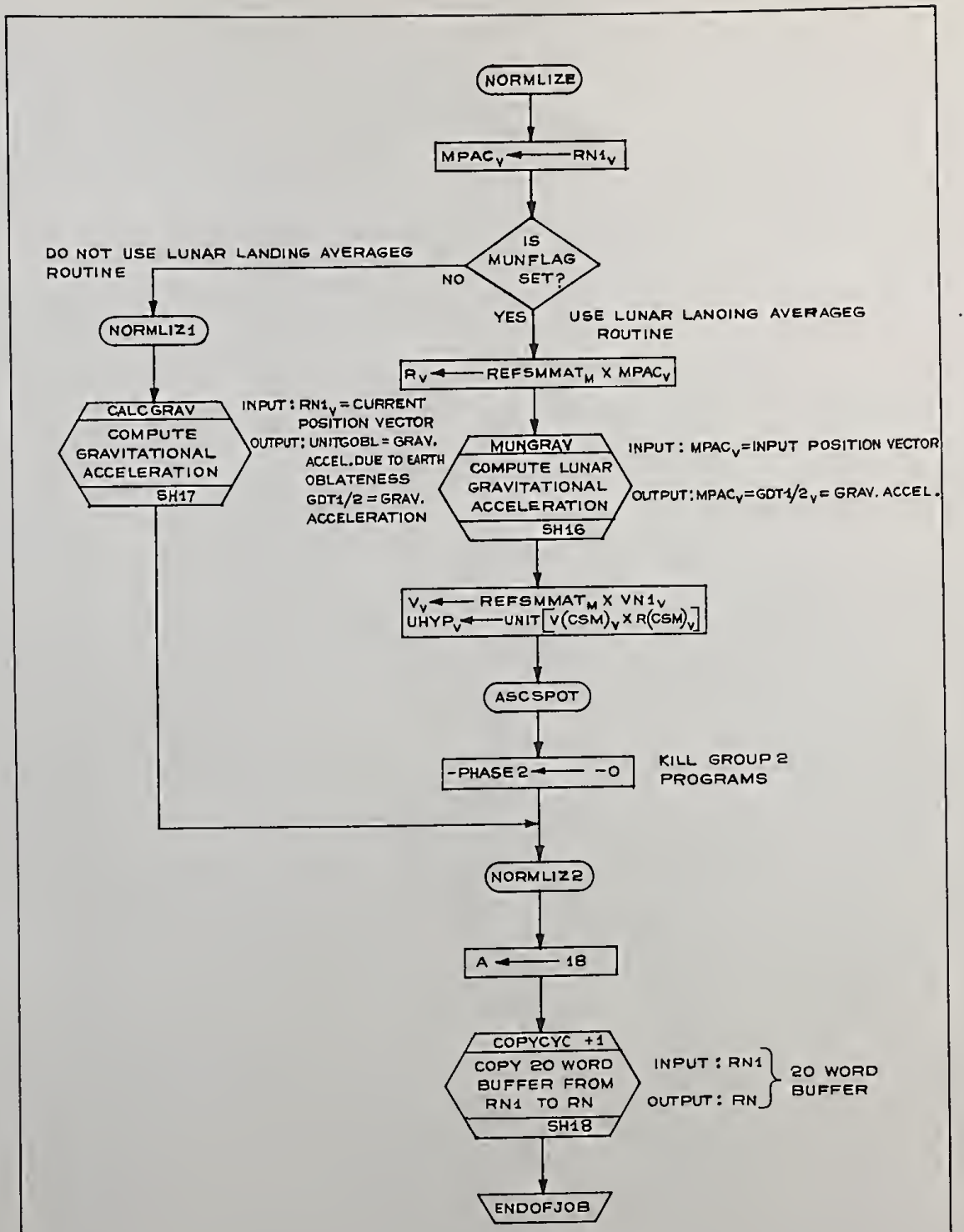
SERVICER

25JUL68
7AUG68
Jan 10, 69
29JUL68
John E. Morse 24 JAN 69

LUMINARY 1C

FC-3850

2 6 20



MIT
INSTRUMENTATION LAB
CAMBRIDGE, MASS.

APOLLO GUIDANCE AND NAVIGATION

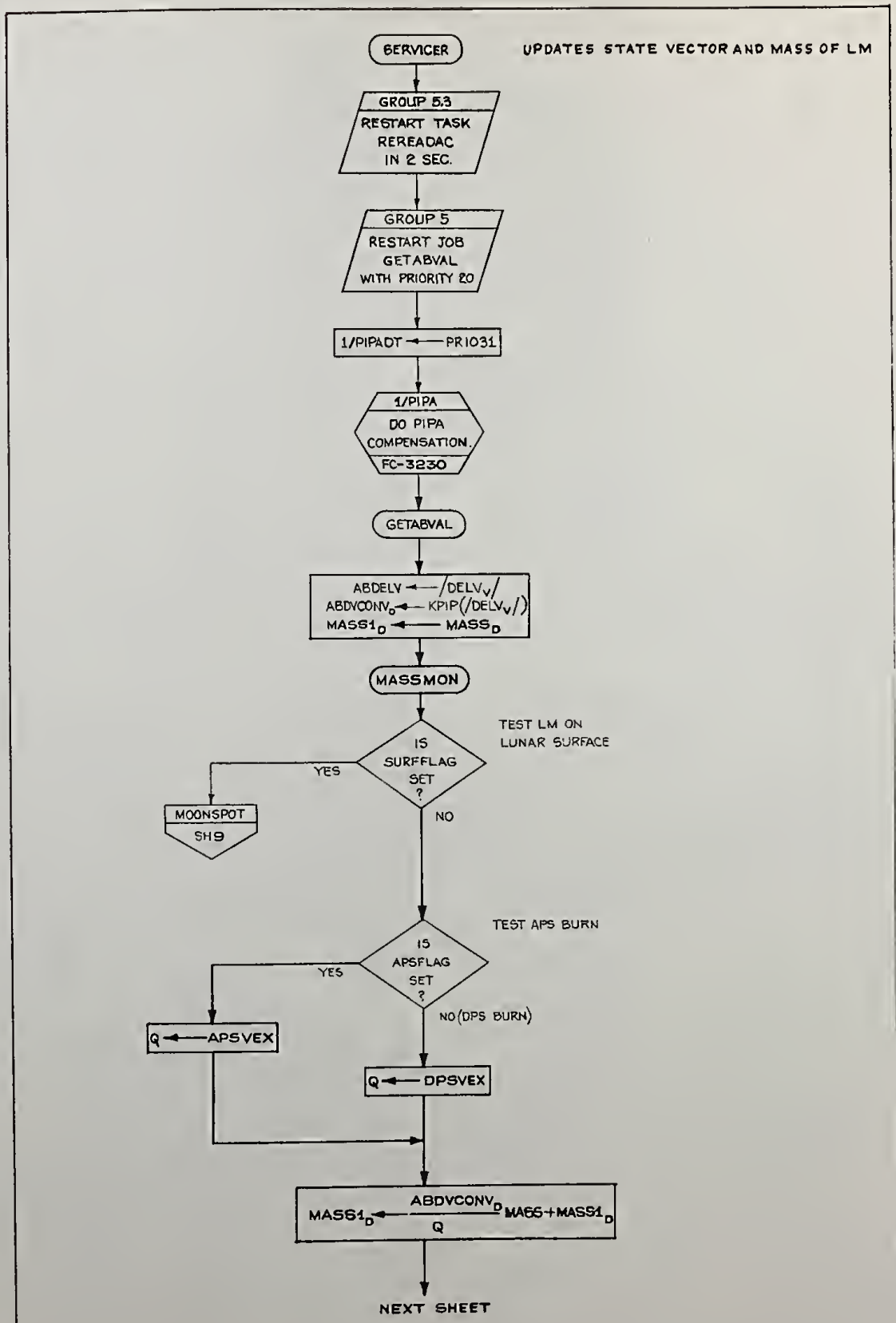
SERVICER

LUMINARY 1C

DOCUMENT NO. E-3850

REV 2

SHEET 7 20



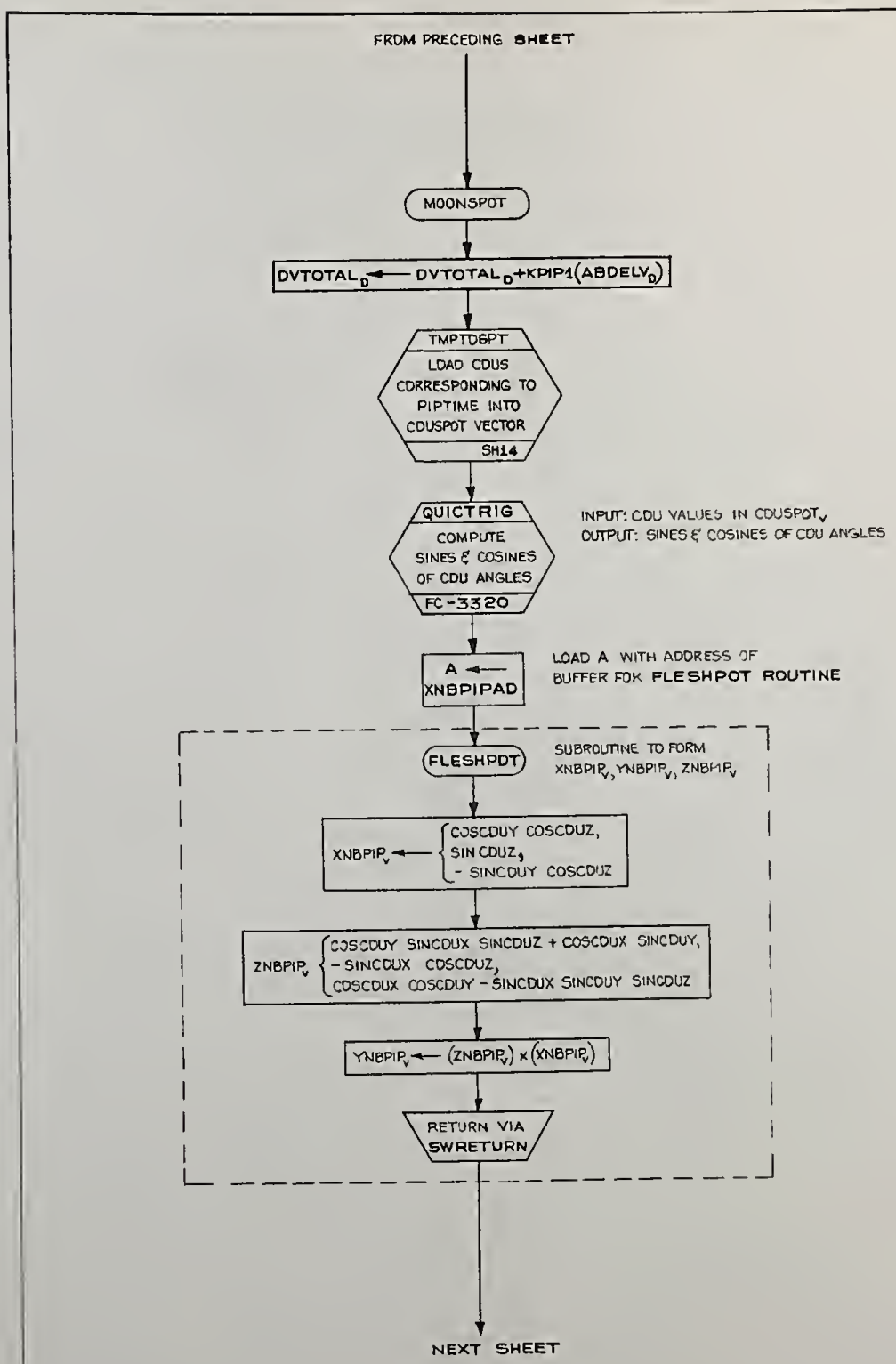
SERVICER

A.C. WILLIAMS 6-12-68
8-7-68
10-4-69
6-24-66
24 NOV 69

LUMINARY 1C

FC-3850

2 8 20



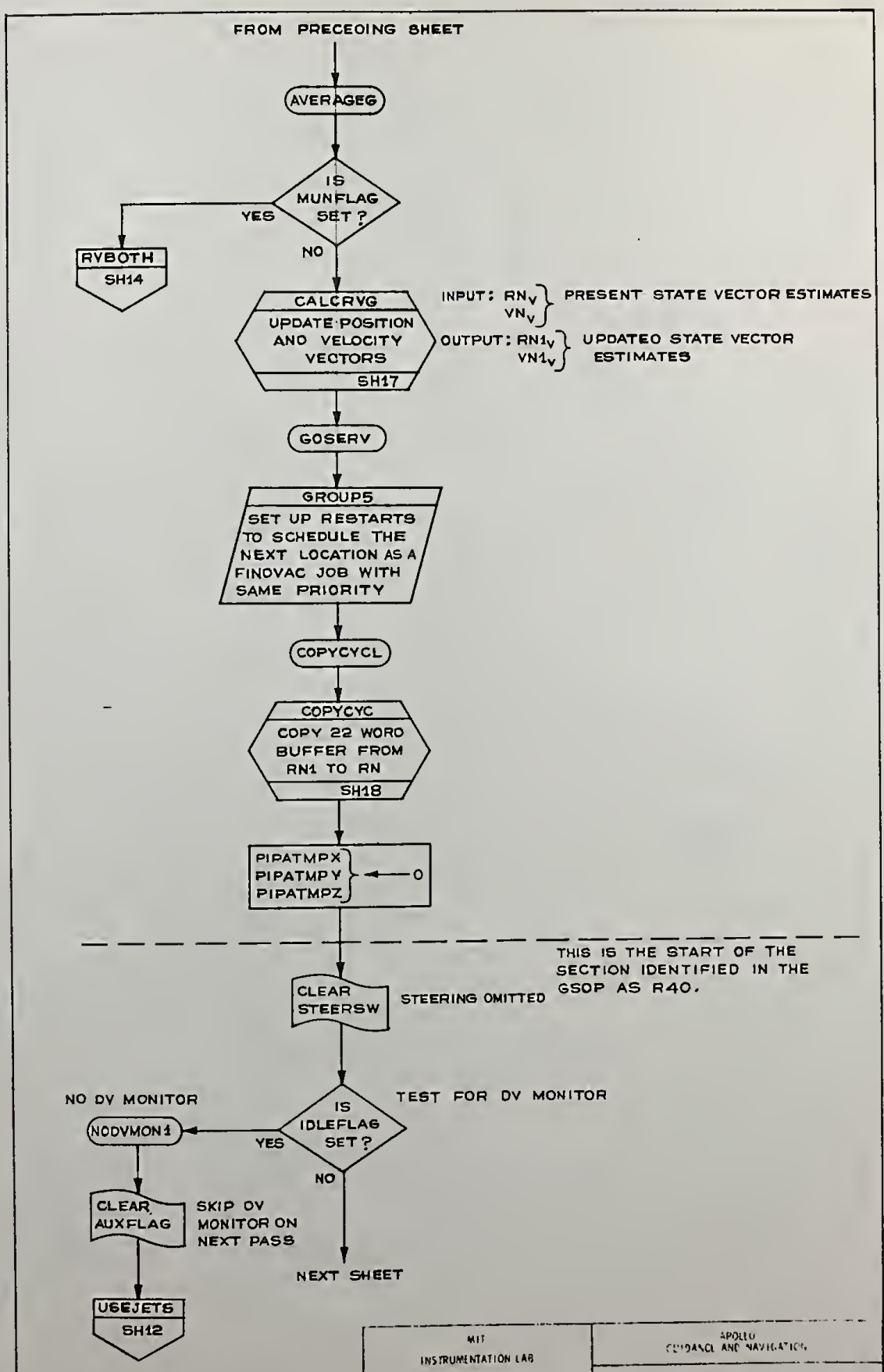
SERVICER

A.C.WILLIAMS 6-14-68
8-7-68
10 Jun 69
6-24-68
24 JAN 69

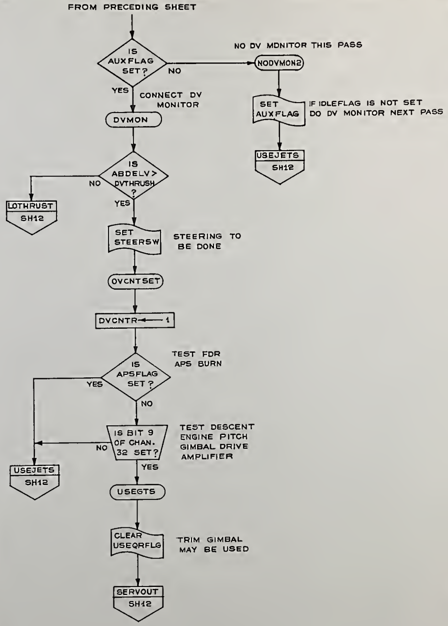
LUMINARY 1C

FC-3850

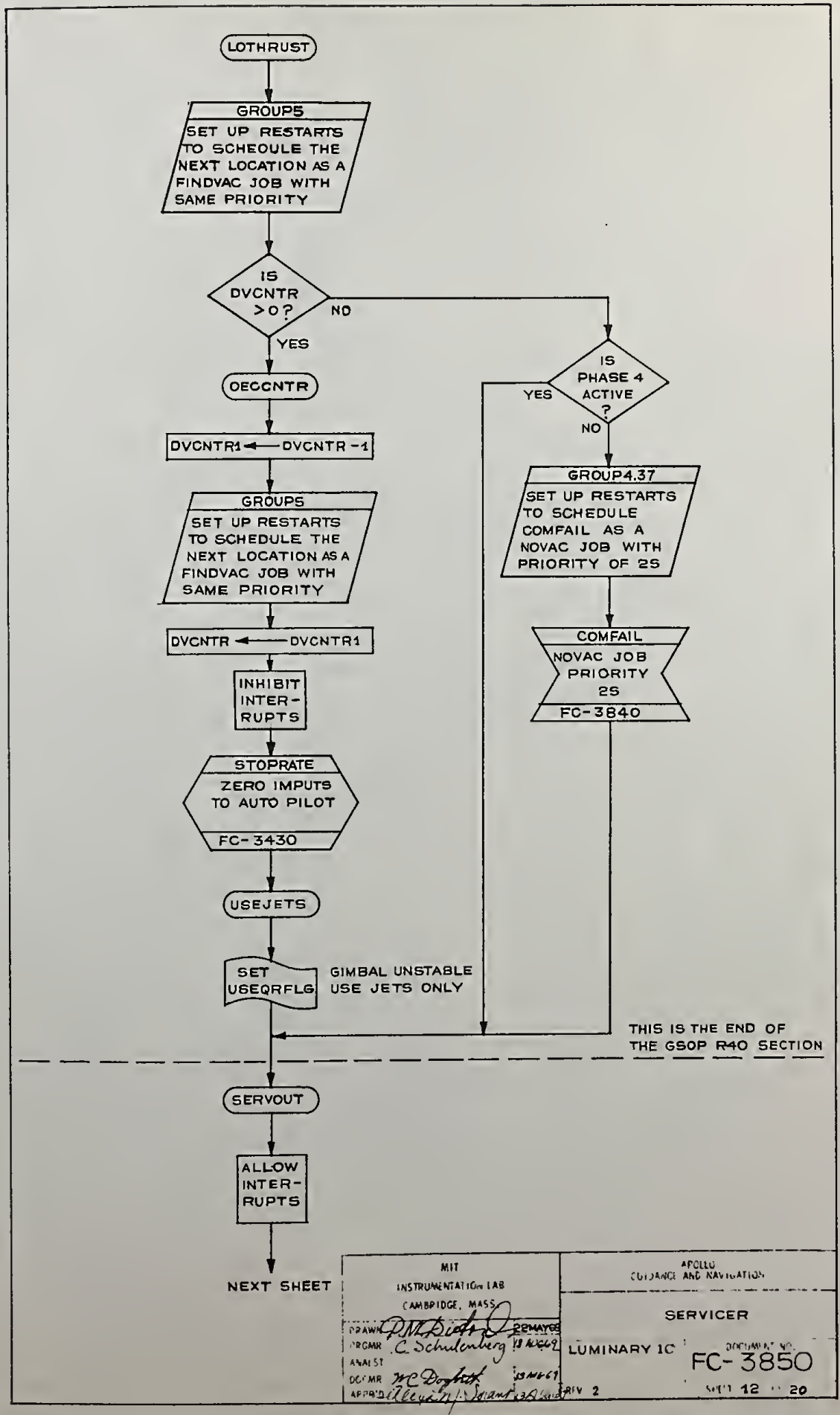
2 9 20



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN P.H. Dietz 21 MAY 69	SERVICER
PROGRAMMER C. Schulenberg 13 AUG 69	LUMINARY 1C
ANALYST	DOCUMENT NO. FC-3850
DSM MGR [illegible] 13 AUG 69	REV 2
APPROVED [illegible]	SHEET 10 OF 20



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.	APOLLO GUIDANCE AND NAVIGATION
DRAWN 22MAY69 PRGMR C Schulenberg 13Aug69 ANALST DOCMR 13AUG69 APPR'D 13AUG69	SERVICER LUMINARY 1C DOCUMENT NO. FC-3850 REV 2 SHEET 11 OF 20



MIT
INSTRUMENTATION LAB
CAMBRIDGE, MASS.

APOLLO
GUIDANCE AND NAVIGATION

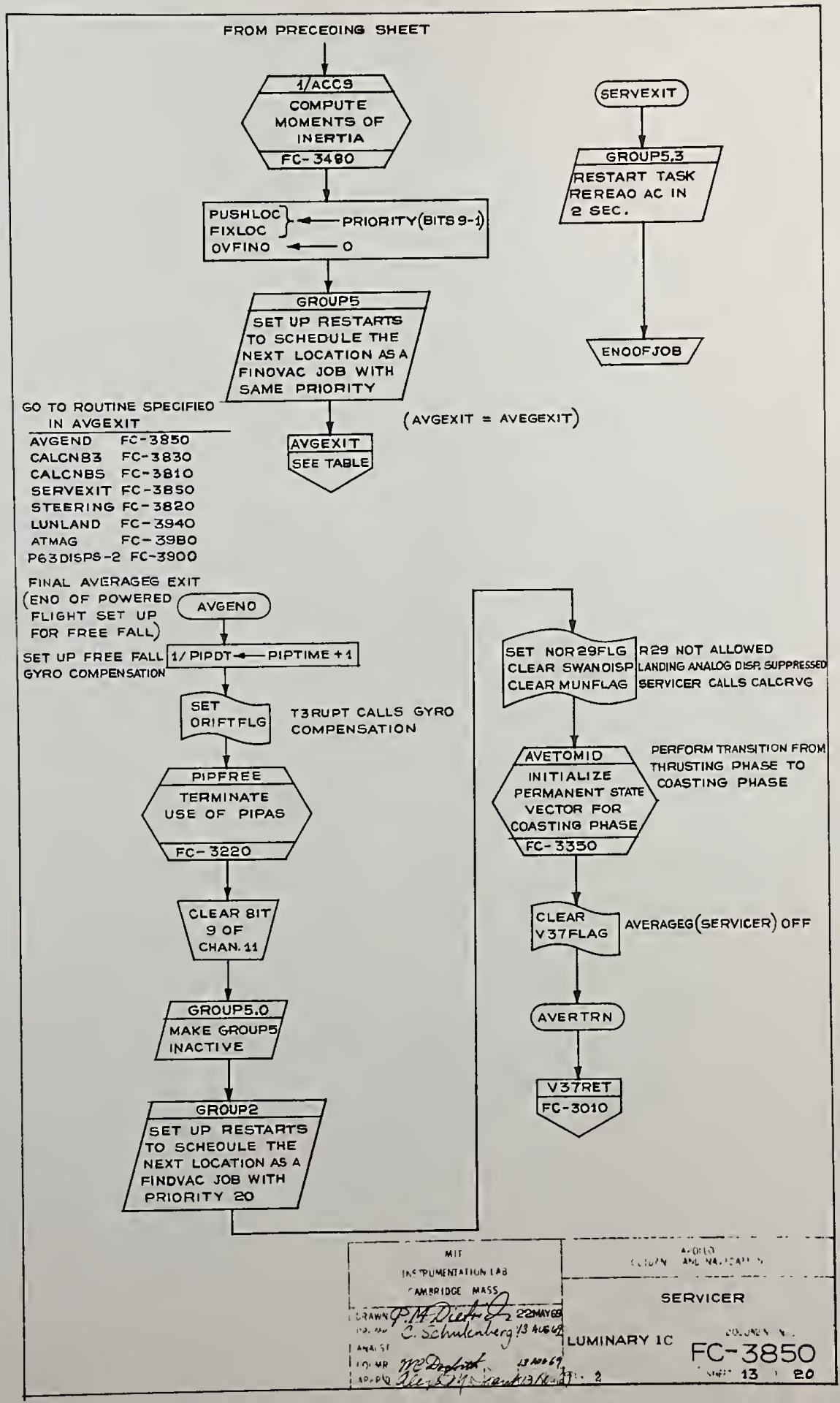
SERVICER

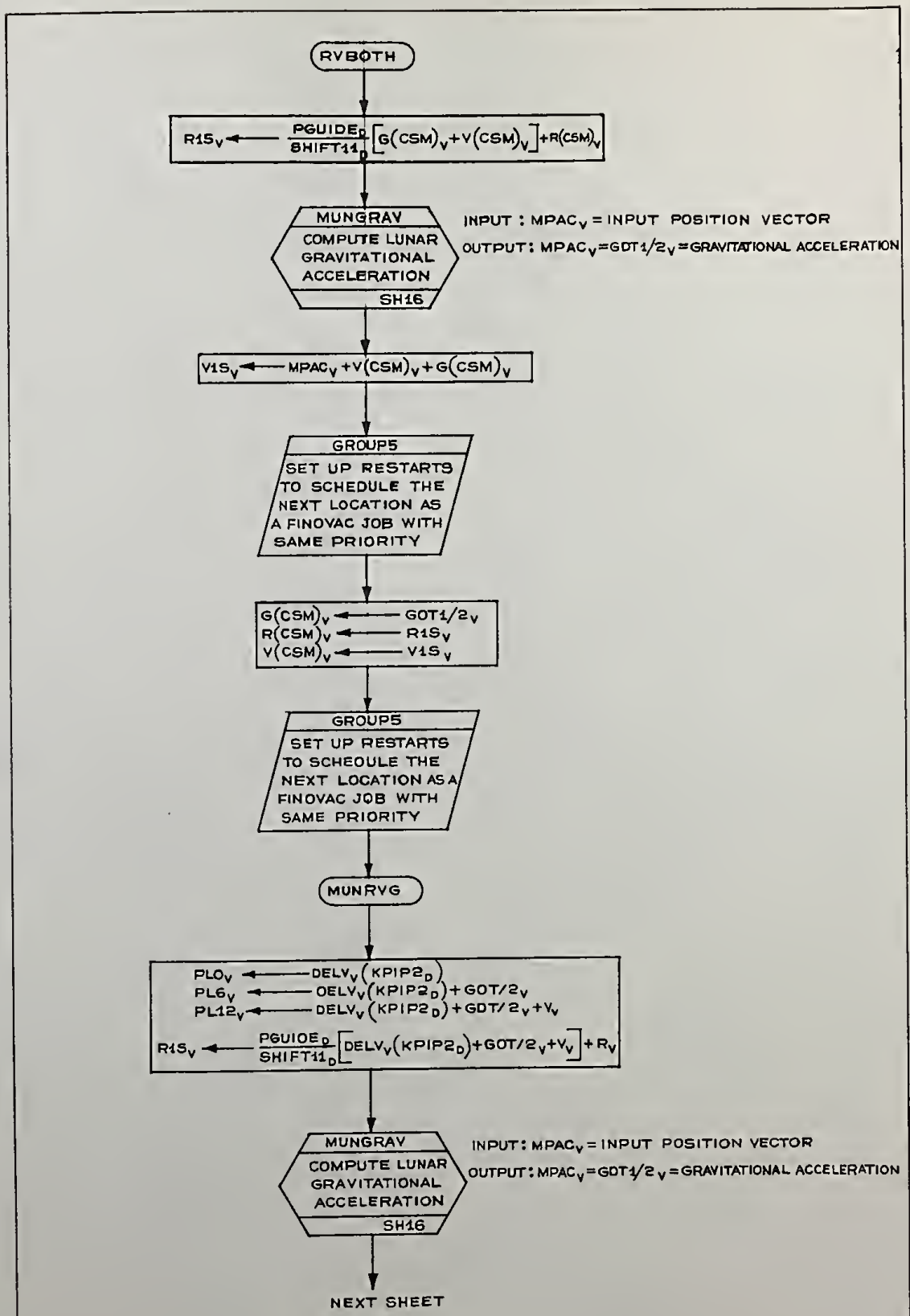
LUMINARY 1C

DOCUMENT NO.
FC-3850

REV 2

SHEET 12 OF 20


FROM PRECEDING SHEET
1/ACCS
COMPUTE MOMENTS OF INERTIA
FC-3480
PUSHLOC
FIXLOC
OVFIND
PRIORITY (BITS 9-1)
0
GROUP5
SET UP RESTARTS TO SCHEDULE THE NEXT LOCATION AS A FINOVAC JOB WITH SAME PRIORITY
AVGEXIT
SEE TABLE
(AVGEXIT = AVEGEXIT)
GO TO ROUTINE SPECIFIED IN AVGEXIT
AVGEND FC-3850
CALCNB3 FC-3830
CALCNB5 FC-3810
SERVEXIT FC-3850
STEERING FC-3820
LUNLAND FC-3940
ATMAG FC-3980
P63DISPS-2 FC-3900
SERVEXIT
GROUP5,3
RESTART TASK REREAD AC IN 2 SEC.
ENDOFJOB
FINAL AVERAGEG EXIT (END OF POWERED FLIGHT SET UP FOR FREE FALL)
AVGEND
SET UP FREE FALL GYRO COMPENSATION
1/PIPDT ← PIPTIME + 1
SET ORIFTFLG
T3RUPT CALLS GYRO COMPENSATION
PIPFREE
TERMINATE USE OF PIPAS
FC-3220
CLEAR BIT 9 OF CHAN. 11
GROUP5.0
MAKE GROUP5 INACTIVE
GROUP2
SET UP RESTARTS TO SCHEDULE THE NEXT LOCATION AS A FINDVAC JOB WITH PRIORITY 20
SET NOR29FLG
CLEAR SWANDISP
CLEAR MUNFLAG
R29 NOT ALLOWED
LANDING ANALOG DISP SUPPRESSED
SERVICER CALLS CALCRVG
AVETOMID
INITIALIZE PERMANENT STATE VECTOR FOR COASTING PHASE
FC-3350
PERFORM TRANSITION FROM THRUSTING PHASE TO COASTING PHASE
CLEAR V37FLAG
AVERAGEG (SERVICER) OFF
AVERTRN
V37RET
FC-3010
MIT
INSTRUMENTATION LAB
CAMBRIDGE MASS
DRAWN P.M. Dietz Jr 22MAY68
C. Schulenberg 13 AUG 68
APPRD W.E. Dapolito 13 AUG 69
SERVICER
LUMINARY 1C
FC-3850
SHEET 13 OF 20



MIT
INSTRUMENTATION LAB
CAMBRIDGE MASS.

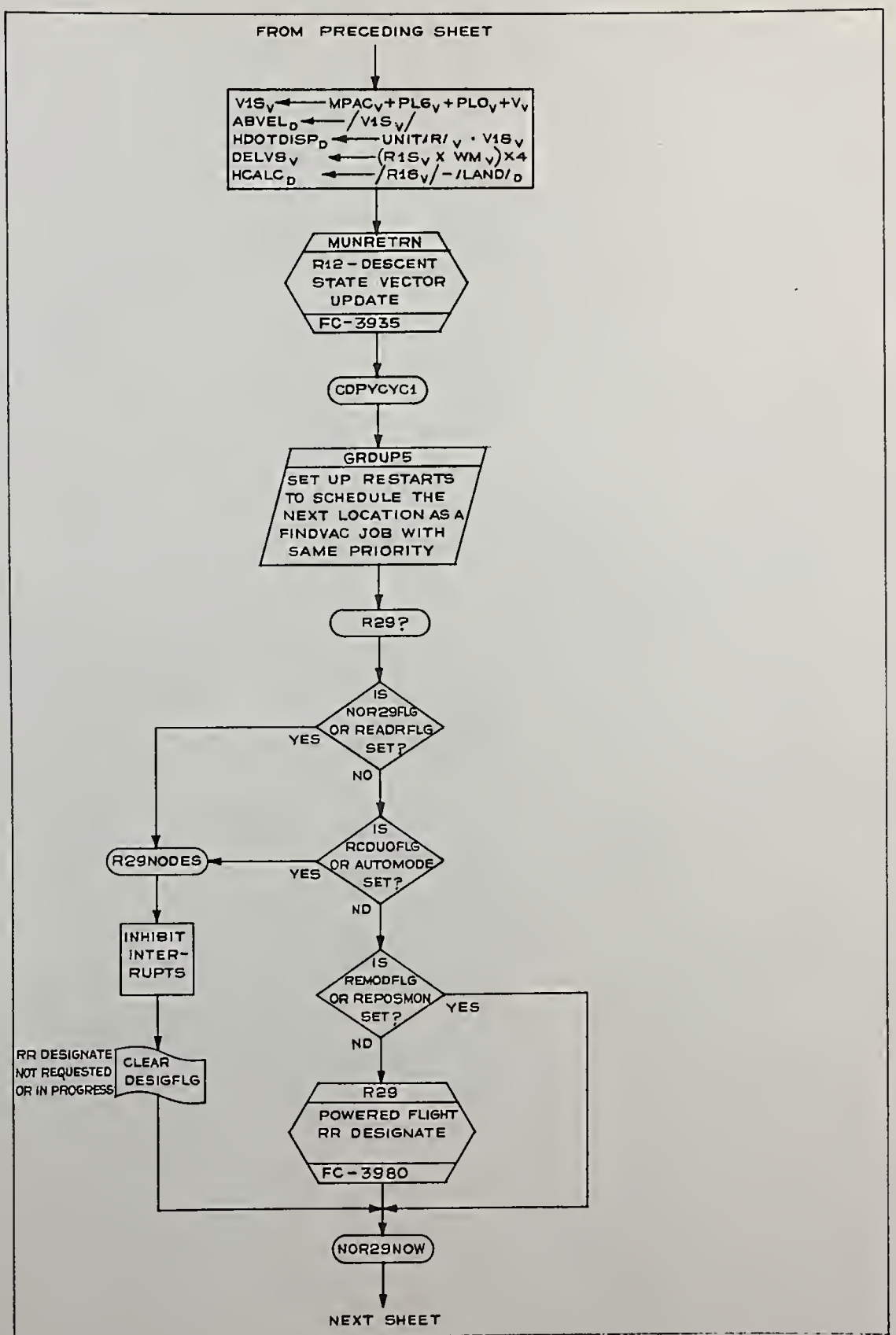
APOLLO GUIDANCE AND NAVIGATION

SERVICER

LUMINARY 1C

DOCUMENT FC-3850

SHEET 14 OF 20



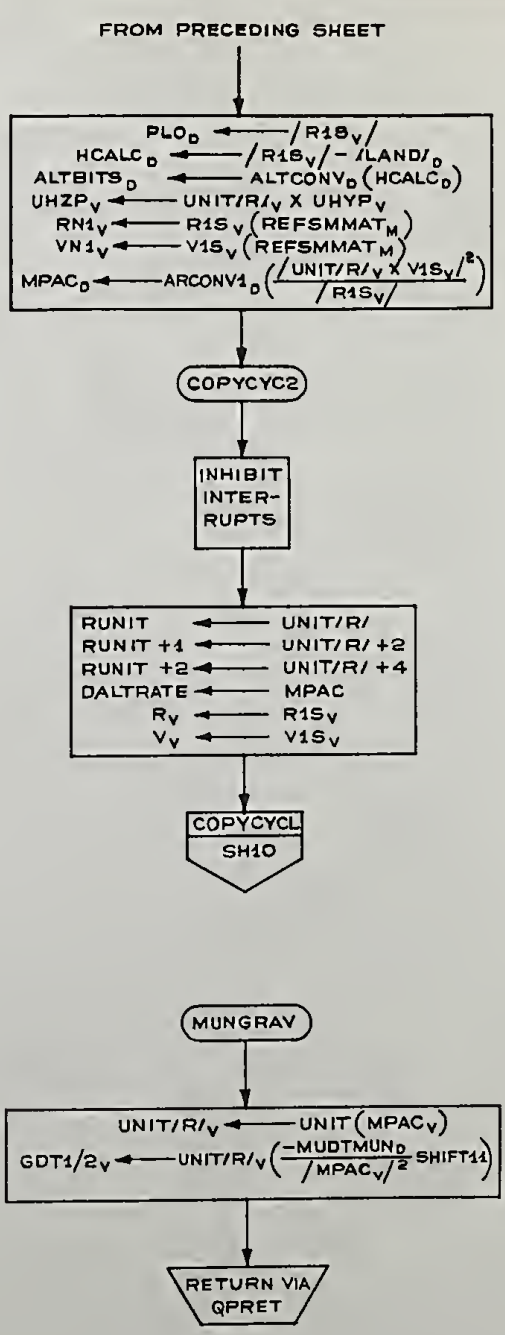
MIT
INSTRUMENTATION LAB
CAMBRIDGE MASS

APOLLO GUIDANCE AND NAVIGATION

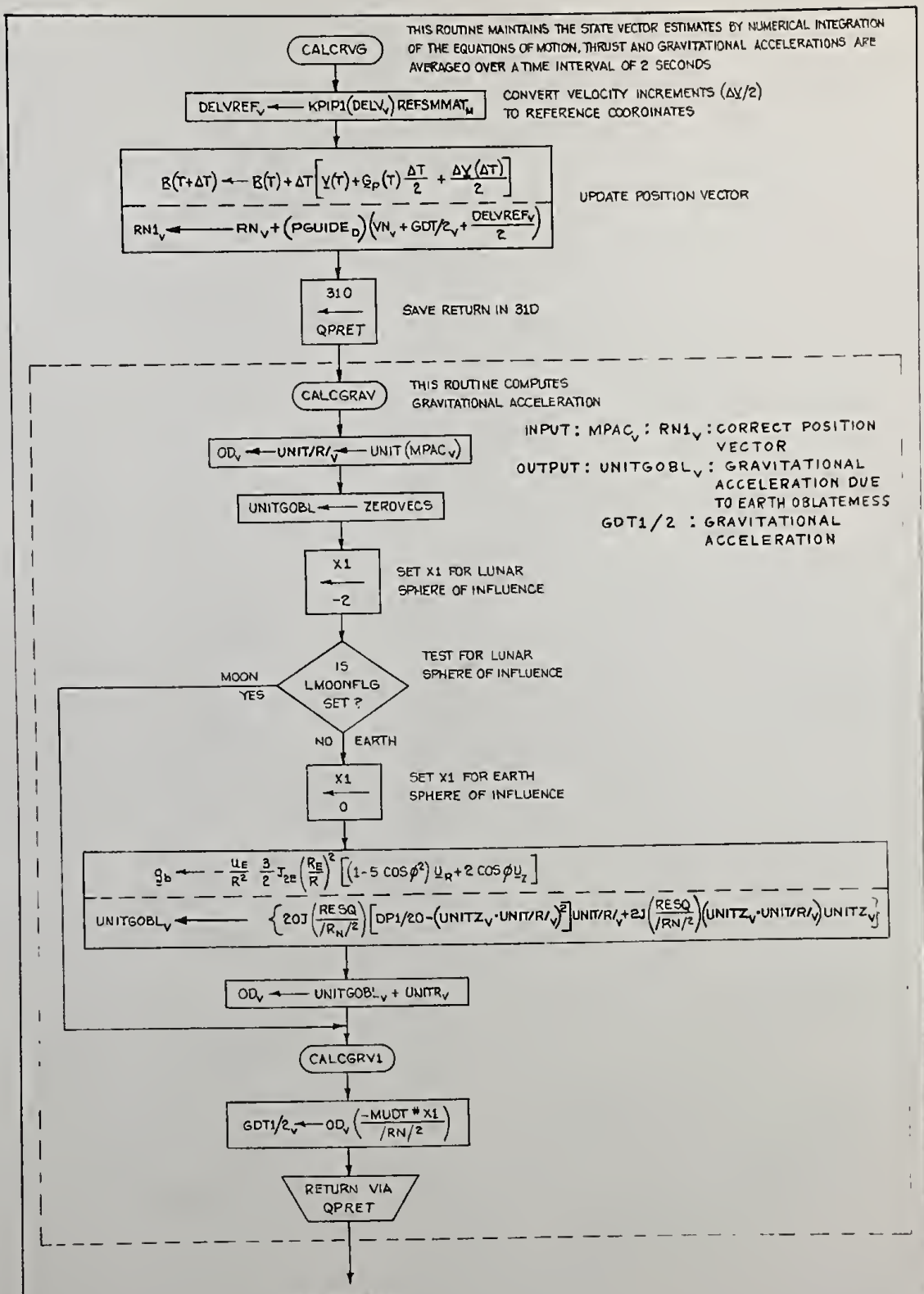
SERVICER

LUMINARY 1C

FC-3850



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN P.M. Dietz 23 MAY 69		SERVICER
PROGR C. Schulenberg 13 AUG 69		
ANALYST		LUMINARY 1C
DOCMR W. McDonough 14 AUG 69		DOCUMENT NO. FC-3850
APPRD		REV 2 SHEET 16 OF 20

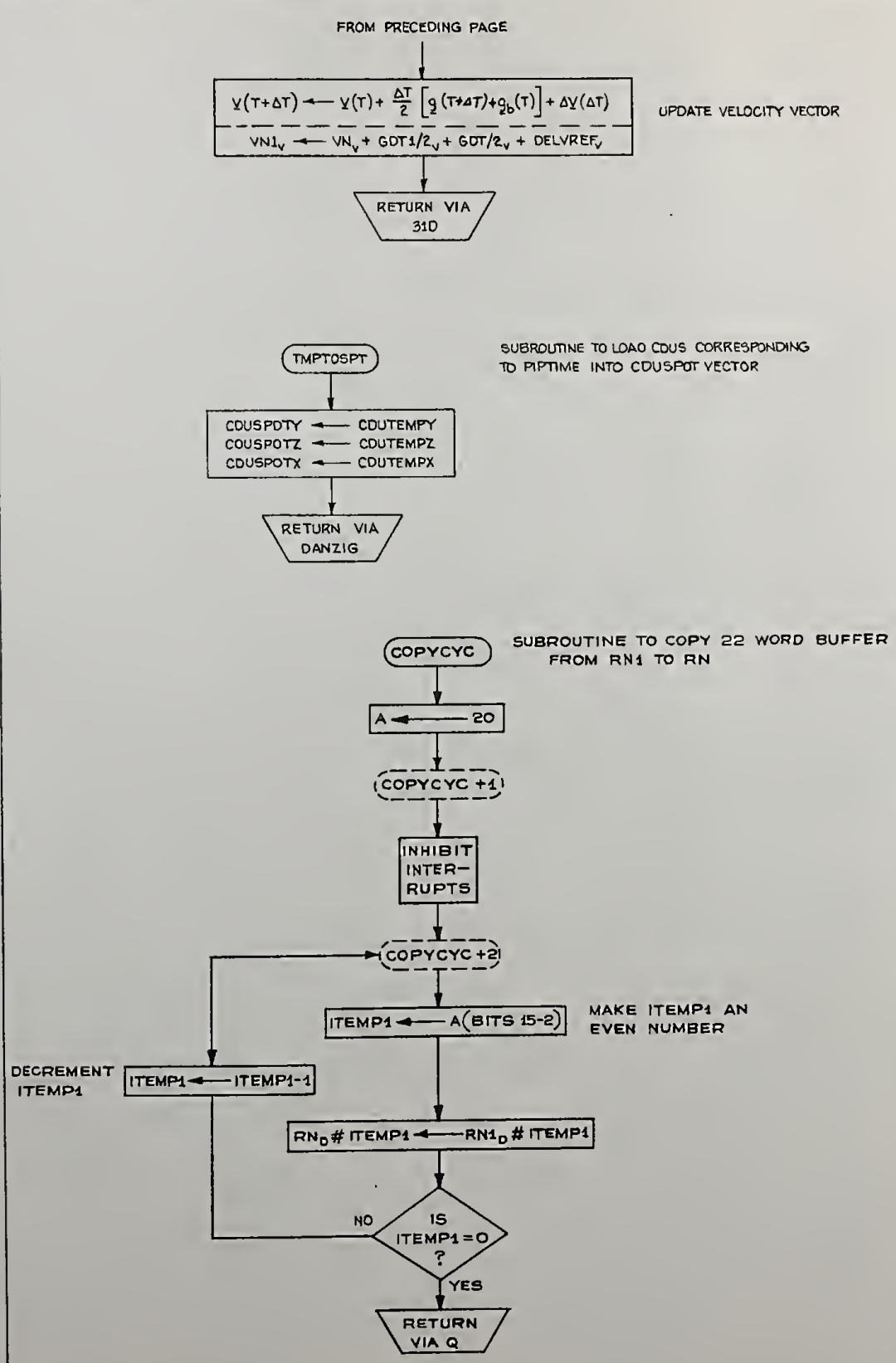


SERVICER

A.C WILLIAMS 6-18-68
R. Covell 8-7-68
10-24-69
6-24-68
John A. Moore 24 JAN 69

LUMINARY 1C

FC-3850


FROM PRECEDING PAGE
$\underline{V}(T+\Delta T) \leftarrow \underline{V}(T) + \frac{\Delta T}{2}\left[\underline{g}(T+\Delta T) + \underline{g}_b(T)\right] + \Delta\underline{V}(\Delta T)$
$VN1_V \leftarrow VN_V + GDT1/2_V + GDT/2_V + DELVREF_V$
UPDATE VELOCITY VECTOR
RETURN VIA 31D
TMPTOSPT
SUBROUTINE TO LOAD CDUS CORRESPONDING TO PIPTIME INTO CDUSPOT VECTOR
CDUSPOTY ← CDUTEMPY
COUSPOTZ ← CDUTEMPZ
CDUSPOTX ← CDUTEMPX
RETURN VIA DANZIG
COPYCYC
SUBROUTINE TO COPY 22 WORD BUFFER FROM RN1 TO RN
A ← 20
COPYCYC +1
INHIBIT INTER-RUPTS
COPYCYC +2
ITEMP1 ← A (BITS 15-2)
MAKE ITEMP1 AN EVEN NUMBER
DECREMENT ITEMP1
ITEMP1 ← ITEMP1-1
RN_D # ITEMP1 ← $RN1_D$ # ITEMP1
IS ITEMP1 = 0 ?
NO
YES
RETURN VIA Q

SUBROUTINES CALLED WHICH ARE FLOWED ON OTHER FLOW CHARTS

SUBROUTINE NAME	FLOW CHART	DESCRIPTION	WHERE CALLED
AVETOMID	FC-3350	INITIALIZE PERMANENT STATE VECTOR FOR COASTING PHASE	SH. 13
COMFAIL	FC-3840	THRUST FAIL PROGRAM	SH. 12
LASTBIAS	FC-3230	LAST GYRO COMPENSATION IN FREE FALL	SH. 2
PIPFREE	FC-3220	TERMINATE USE OF PIPAS	SH. 13
QUICTRIG	FC-3320	COMPUTE SINES AND COSINES OF CDU ANGLES	SH. 9
R10,R11	FC-3930	LANDING RADAR MONITOR	SH. 4
R29	FC-3980	POWERED FLIGHT RR DESIGNATE	SH. 15
STOPRATE	FC-3430	ZERO INPUTS TO AUTOPILOT	SH. 12
VARDELAY	FC-3040	DELAY ACTIVE TASK	SH. 2, 4
1/ACCS	FC-3490	COMPUTE MOMENTS OF INERTIA	SH. 13
1/PIPA	FC-3230	COMPENSATE PIPAS AND GYROS	SH. 8

ERASABLE LOCATIONS USED

AGC TAG	GSOP SYMBOL	MEANING	ENGINEERING UNITS	AGC UNITS	AGC SCALING
$DVTOTAL_D$		ACCUMULATED DELTA-V	FEET/SEC	M CSEC	2^{-7}
$GDT1/2_V$		GRAVITATIONAL ACCELERATION VECTOR (DELTA TIME)	FEET/SEC	M CSEC	2^{-7}
$MASS1_D$		VEHICLE MASS	POUNDS	KG	2^{-16}
$PGUIDE_D$		DELTA PIPTIME	SECONDS	CSEC	2^{28}
$RN1_V$		LM POSITION VECTOR	FEET	METERS	2^{-29}
$VN1_V$		LM VELOCITY VECTOR	FEET/SEC	M/CSEC	2^{-7}
$XNBPIP_V$		STABLE MEMBER TO NAVIGATION BASE TRANSFORMATION MATRIX FOR LAST PIP TIME	–	–	2^{-1}
$YNBPIP_V$			–	–	2^{-1}
$ZNBPIP_V$			–	–	2^{-1}

FLAGS

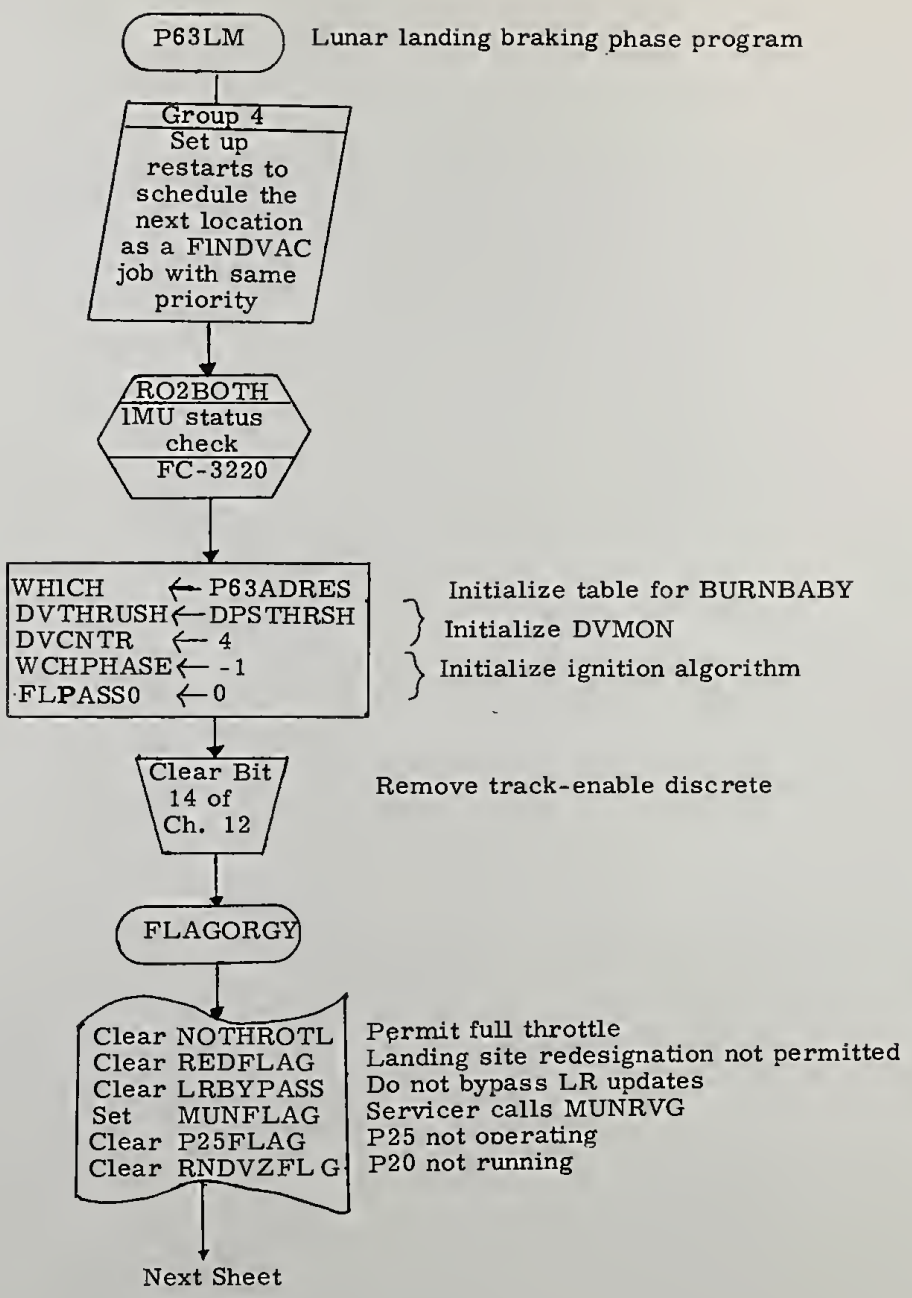
NAME	MEANING WHEN SET	MEANING WHEN CLEAR	WHERE SET	WHERE CLEARED	WHERE TESTED
APSFLAG FLAG 10 BIT 13	APS BURN	DPS BURN			SH. 8, 11
AUTOMODE FLAG 12 BIT 2	RR NOT IN AUTO MODE	RR IN AUTO MODE			SH. 15
AUXFLAG FLAG 6 BIT 2	IF IDLEFLAG IS NOT SET, SERVICER WILL DO DVMON ON NEXT PASS	SERVICER WILL SKIP DVMON ON NEXT PASS	SH. 11	SH. 10	SH. 11
AVEGFLAG FLAG 7 BIT 5	AVERAGEG (SERVICER) DESIRED	AVERAGEG (SERVICER) NOT DESIRED	SH. 2		SH. 4
DESIGFLG FLAG 14 BIT 10	RR DESIGNATE REQUESTED OR IN PROGRESS	RR DESIGNATE NOT REQUESTED OR IN PROGRESS		SH. 15	
DRIFTFLG FLAG 2 BIT 15	T3RUPT CALL GYRO COMPENSATION	T3RUPT DOES NO GYRO COMPENSATION	SH. 13	SH. 2	
MUNFLAG FLAG 6 BIT 8	USE LUNAR LANDING AVERAGEG	DO NOT USE LUNAR LANDING AVERAGEG		SH. 13	SH. 4, 7, 10
NOR29FLG FLAG 3 BIT 11	R29 NOT ALLOWED	R29 ALLOWED	SH. 13		SH. 15
RCDU0FLG FLAG 12 BIT 13	RR CDU'S BEING ZEROED	RR CDU'S NOT BEING ZEROED			SH. 15
READRFLG FLAG 3 BIT 9	READING RR DATA PURSUANT TO R29	NOT READING RR DATA PURSUANT TO R29			SH. 15
REMODFLG FLAG 12 BIT 14	CHANGE IN ANTENNA MODE BEEN REQUESTED	NO REMODE REQUEST OR OCCURRING			SH. 15
REPOSMON FLAG 10 BIT 11	RR REPOSITION IS TAKING PLACE	NO REPOSITION TAKING PLACE			SH. 15
STEERSW FLAG 2 BIT 11	STEERING TO BE DONE	STEERING OMITTED	SH. 11	SH. 10	
SURFFLAG FLAG 8 BIT 8	LM ON LUNAR SURFACE	LM NOT ON LUNAR SURFACE			SH. 8
SWANDISP FLAG 7 BIT 11	LANDING ANALOG DISPLAYS ENABLED	LANDING ANALOG DISPLAYS SUPPRESSED		SH. 13	
USEQRFLG FLAG 13 BIT 14	GIMBAL UNUSABLE. USE JETS ONLY	TRIM GIMBAL MAY BE USED	SH. 12	SH. 11	
V37FLAG FLAG 7 BIT 6	AVERAGEG (SERVICER) RUNNING	AVERAGEG (SERVICER) OFF	SH. 2	SH. 13	

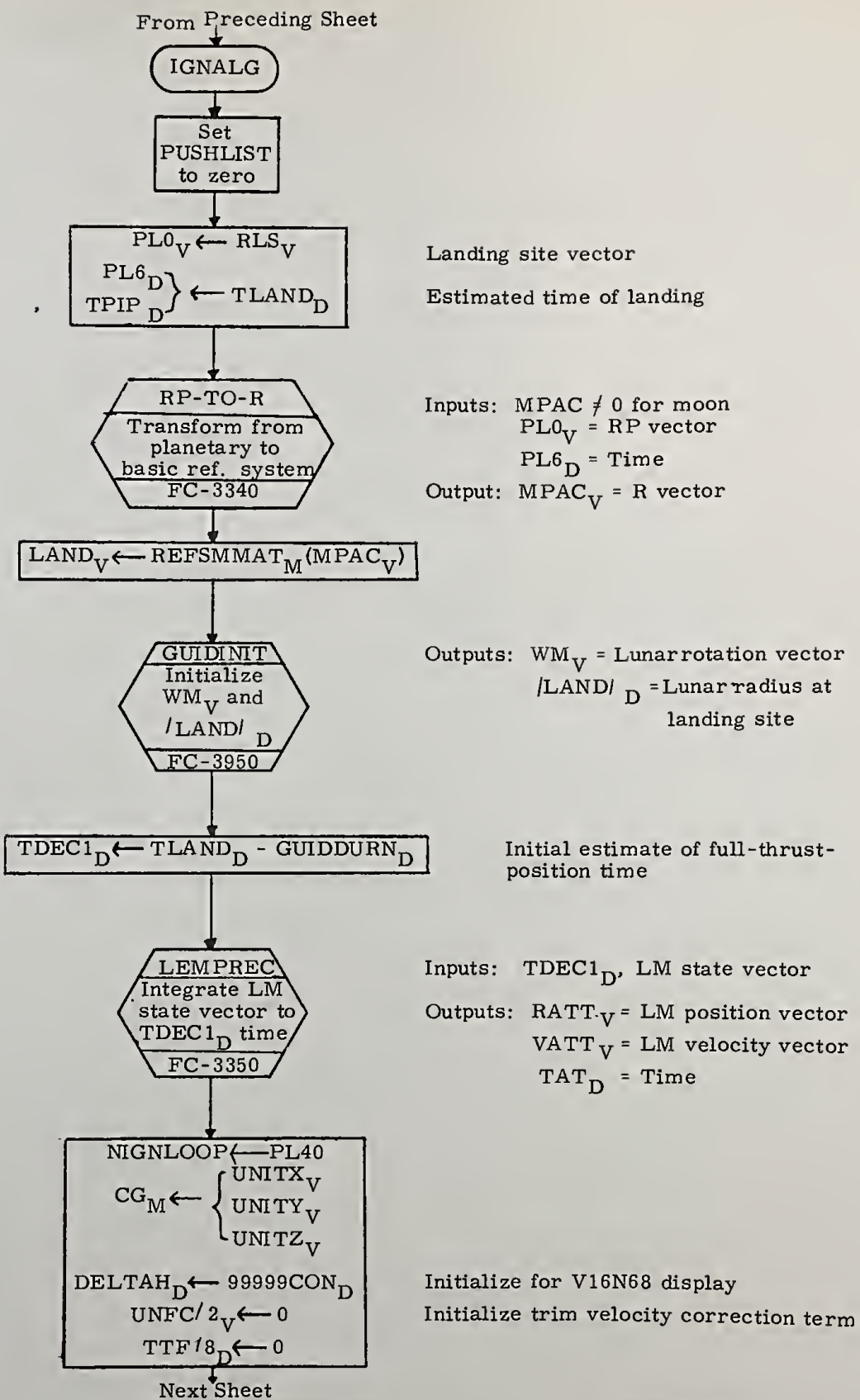
LUNAR LANDING

MAJOR SUBROUTINES ON THIS CHART

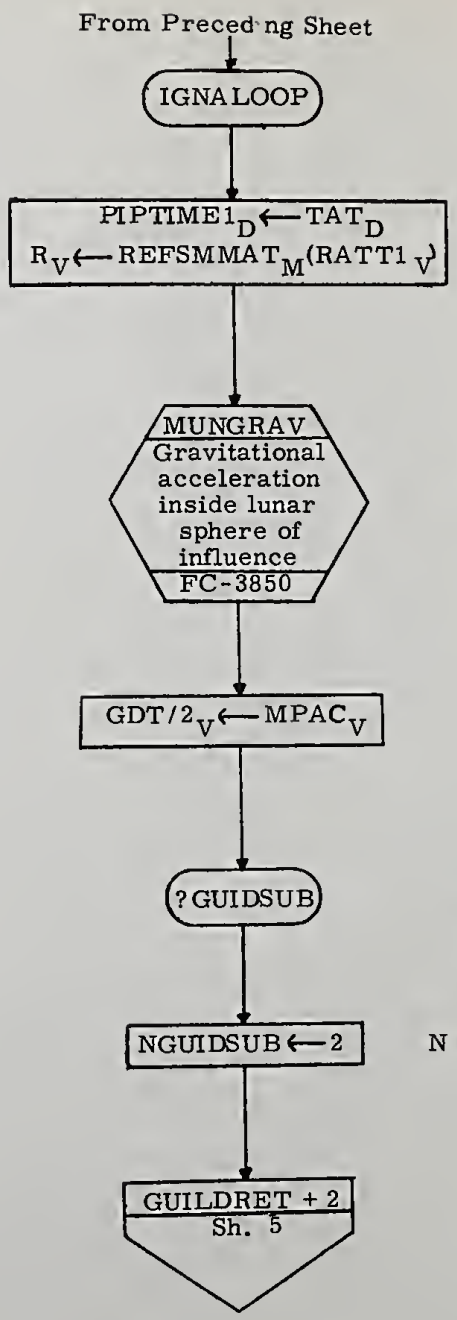
P63LM	LUNAR LANDING BRAKING PHASE	SH 2
GUILDRET	GUIDANCE ENTRY FROM R13 ROUTINE	SH 5
P63DISPS	P63 DISPLAY ROUTINE ENTRY	SH 27
FLATOUT	FULL THROTTLE ON DPS ENGINE	SH 39

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.			APOLLO GUIDANCE AND NAVIGATION	
DRAWN		9/3/68	Lunar Landing	
PRGMR		11-25-68		
ANALST			LUMINARY 1C	DOCUMENT NO. FC-3900
DOCMR		9/30/69		
APPR'D	Roberta M. Eutsler	11/25/69	REV	SHEET 1 OF 46


P63LM
Lunar landing braking phase program
Group 4
Set up restarts to schedule the next location as a FINDVAC job with same priority
RO2BOTH
IMU status check
FC-3220
WHICH ← P63ADRES
DVTHRUSH ← DPSTHRSH
DVCNTR ← 4
WCHPHASE ← -1
FLPASS0 ← 0
Initialize table for BURNBABY
Initialize DVMON
Initialize ignition algorithm
Clear Bit 14 of Ch. 12
Remove track-enable discrete
FLAGORGY
Clear NOTHROTL
Clear REDFLAG
Clear LRBYPASS
Set MUNFLAG
Clear P25FLAG
Clear RNDVZFLG
Permit full throttle
Landing site redesignation not permitted
Do not bypass LR updates
Servicer calls MUNRVG
P25 not operating
P20 not running
Next Sheet



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN D Lickteig	9/30/69	Lunar Landing	
PRGMR		LUMINARY 1C	DOCUMENT NO. FC-3900
ANALST			
DOCMR W Digbotti	9/30/69	REV	SHEET 3 OF 46
APPR'D Robert M Eyles	11/28/69		



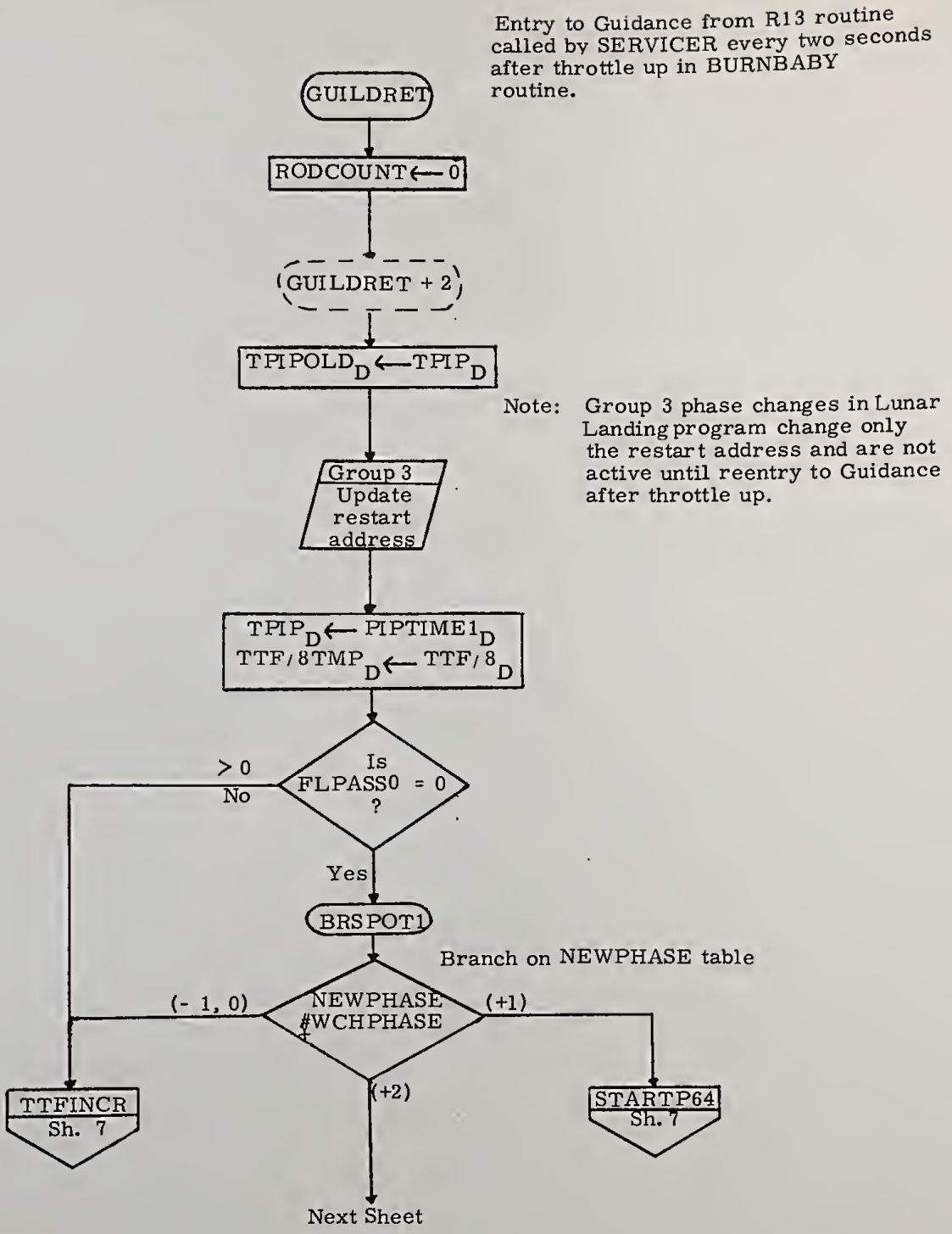
Input: $MPAC_V$ = R vector

Output: $MPAC_V$ = $GDT1/2_V$

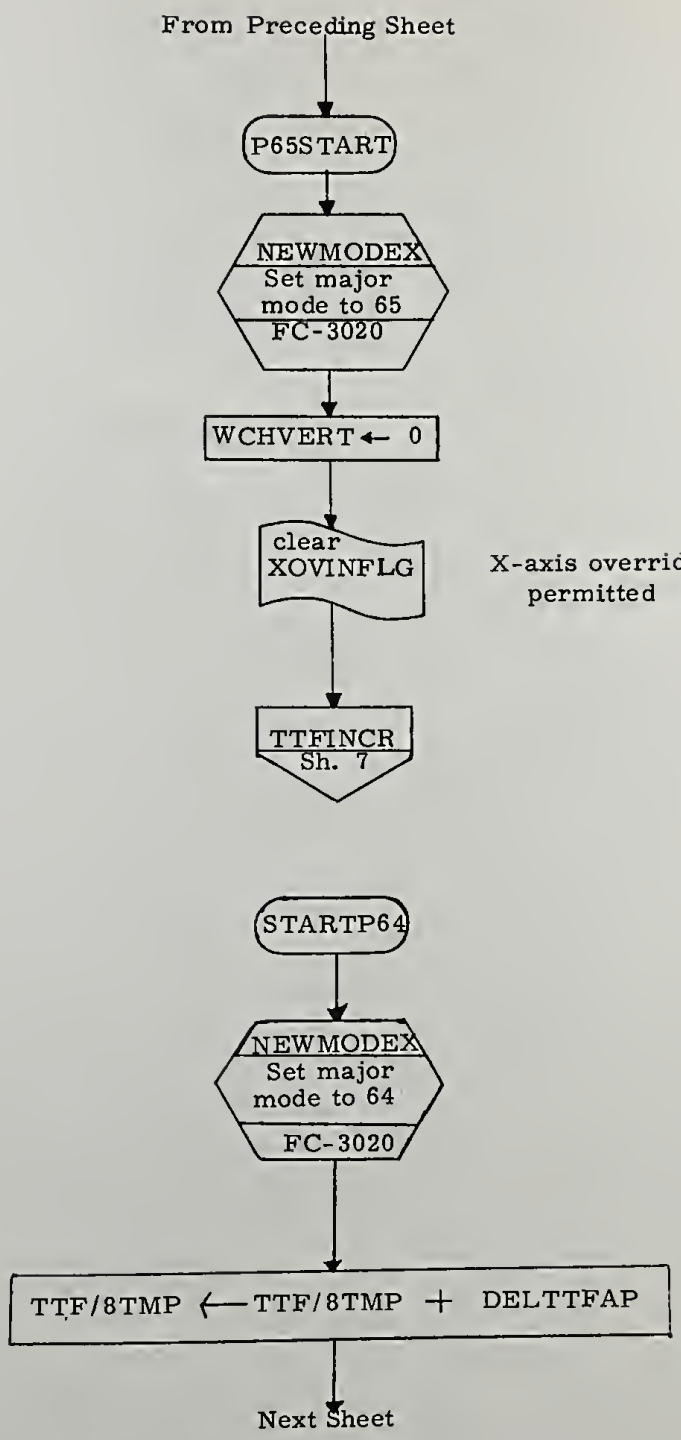
Delivers N passes of quadratic guidance

N = 3

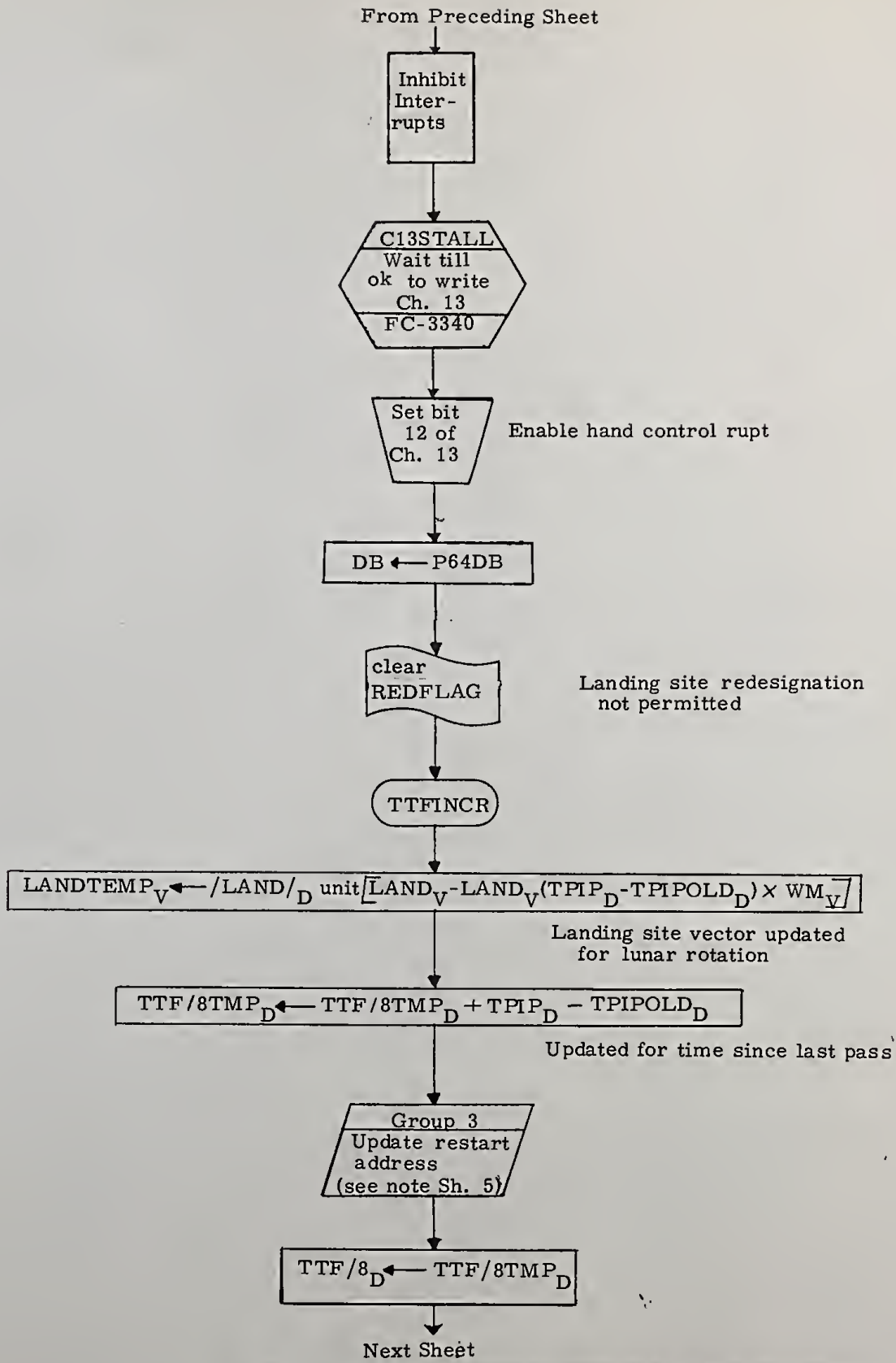
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN E Lutkenhaus	9/23/68	Lunar Landing	
PRGMR		PRELIMINARY 1C	DOCUMENT NO. FC-3900
ANALST			
DOCMR W Dyghrit	9/30/69	REV	SHEET 4 OF 46
APPR'D Robert M Ensey	11/25/69		



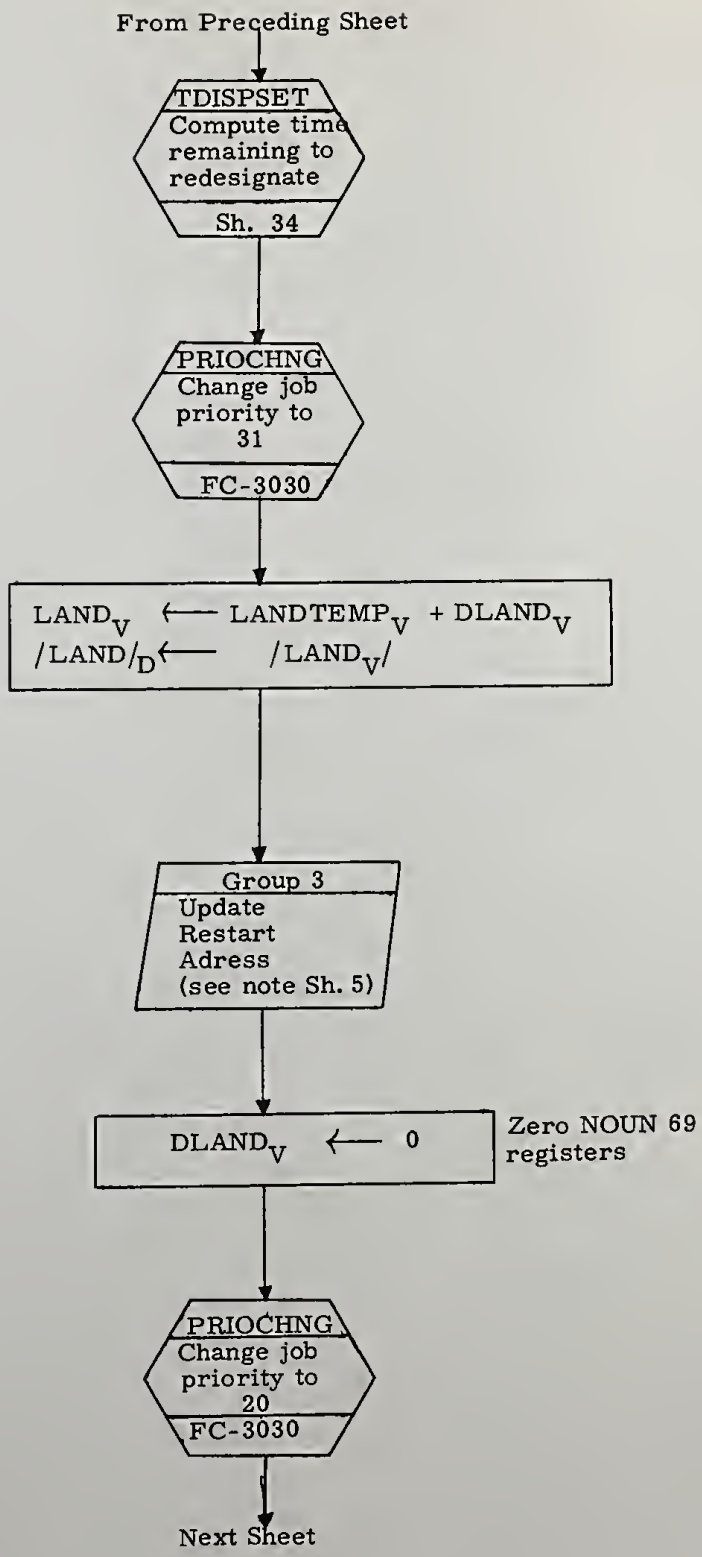
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		Lunar Landing	
PRGMR			
ANALST		LUMINARY 1C	DOCUMENT NO. FC-3900
DOCMR	W Boyhtd	9/30/69	
APPR'D	Robert M Eng	10/6/69	REV SHEET 5 OF 46



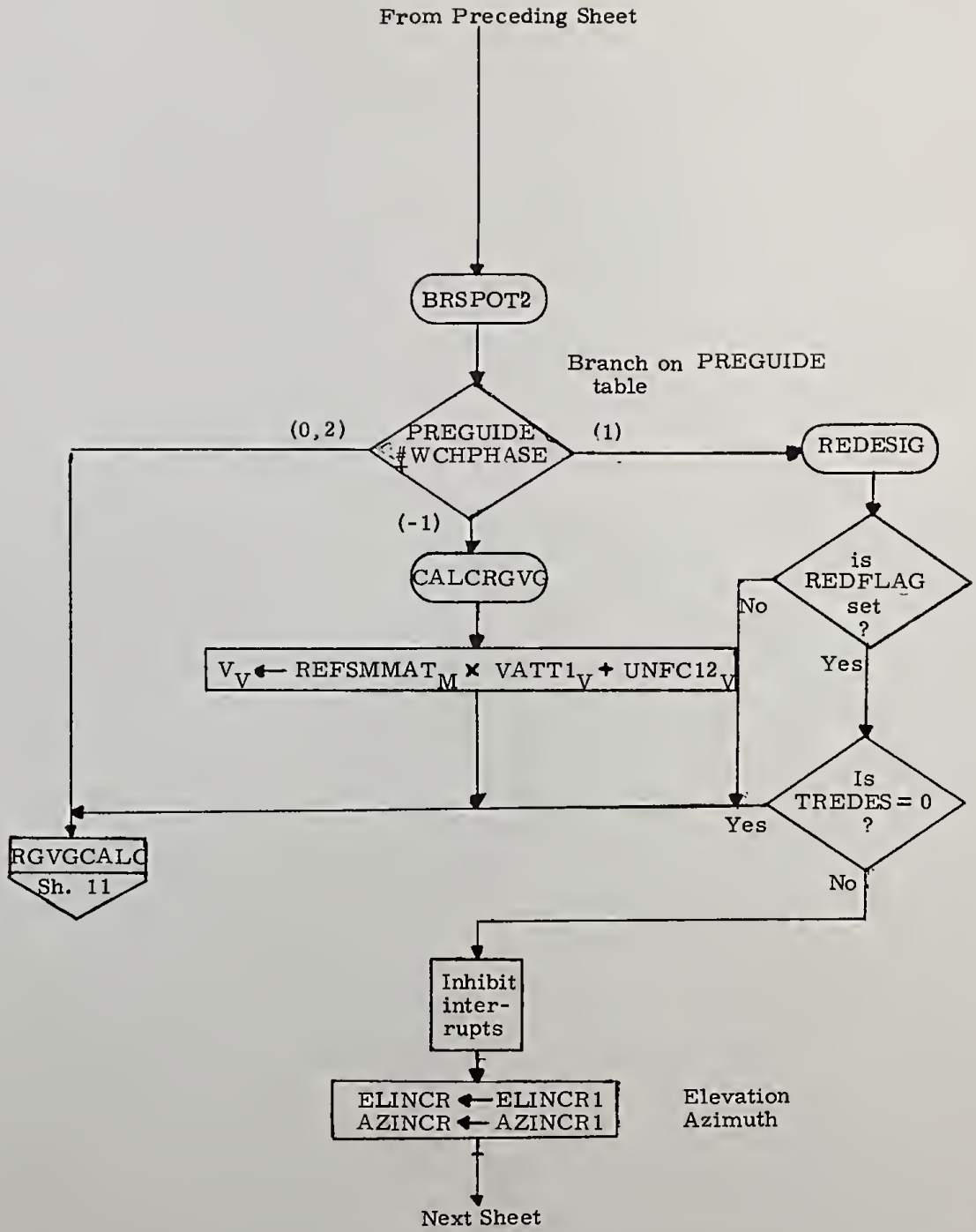
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		Lunar Landing	
PRGMR			
ANALST		LUMINARY 1C	DOCUMENT NO. FC-3900
DOCMR	9/30/69		
APPR'D	11/5/69	REV	SHEET 6 OF 46



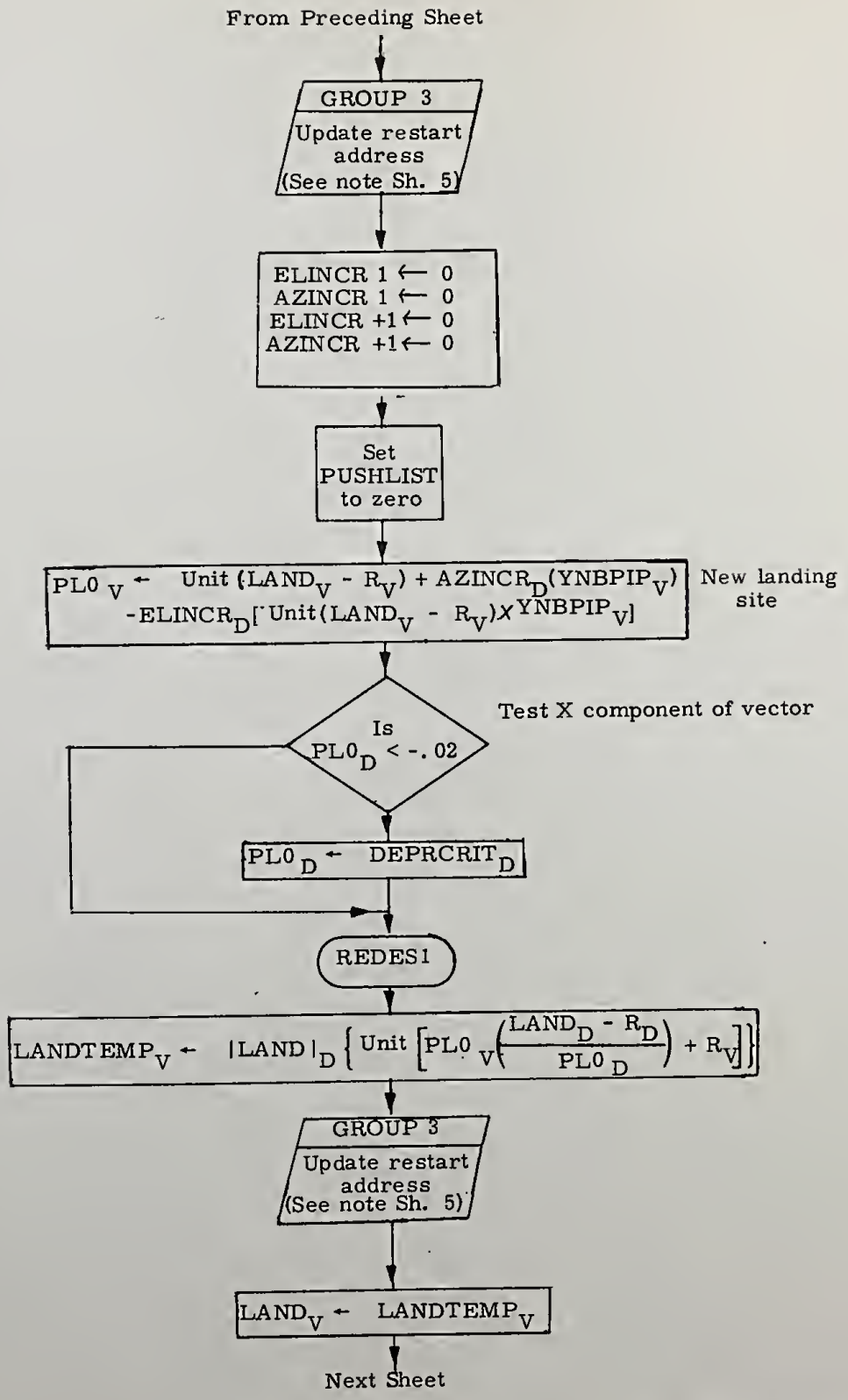
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		Lunar Landing	
PRGMR			
ANALST		LUMINARY 1C	DOCUMENT NO. FC-3900
DOCMR	9/30/69		
APPR'D	11/26/69	REV	SHEET 7 OF 46



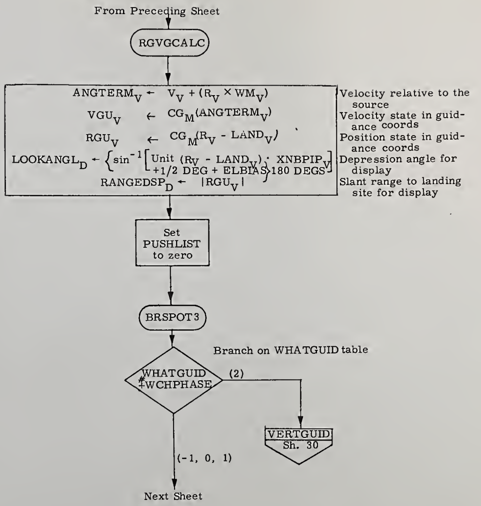
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		Lunar Landing	
PRGMR		LUMINARY 1C	DOCUMENT NO. FC-3900
ANALST			
DOCMR	9/30/69		
APPR'D	11/25/69	REV	SHEET 8 OF 46



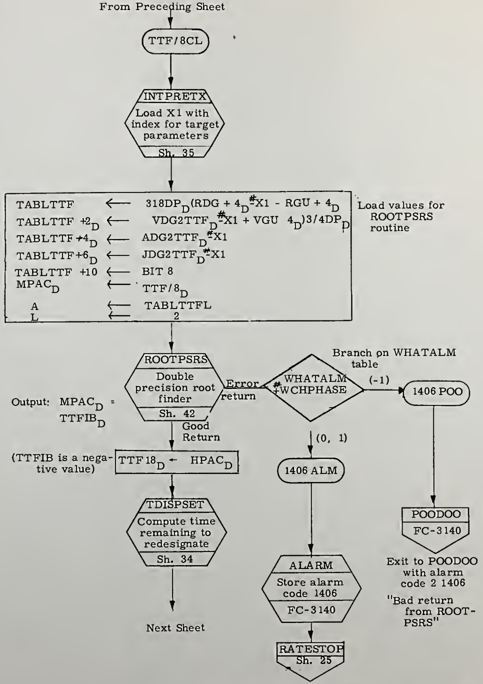
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		Lunar Landing	
PRGMR		LUMINARY 1C	DOCUMENT NO. FC-3900
ANALST			
DOCMR	9/30/69	REV	SHEET 9 OF 46
APPR'D	11/25/69		



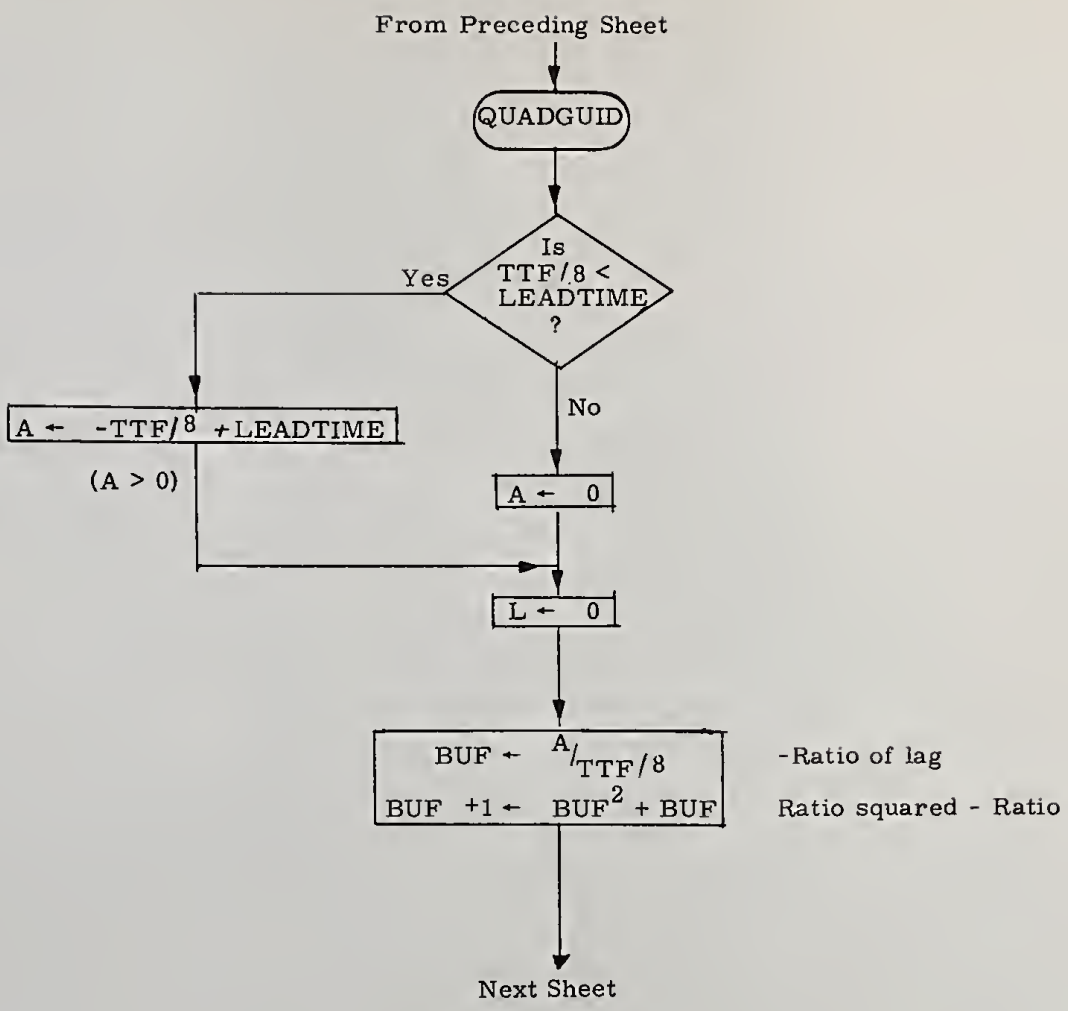
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		Lunar Landing	
PRGMR			
ANALST		LUMINARY 1C	DOCUMENT NO. FC-3900
DOCMR	9/24/69		
APPR'D	11/25/67	REV	SHEET 10 OF 46



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		Lunar Landing	
PRGMR			
ANALST		LUMINARY 1C	DOCUMENT NO. FC-3900
DOCMR W. Dayhitt	9/30/69		
APPR'D RM Ensue	11/25/69	REV	SHEET 11 of 46



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		Lunar Landing	
PRGMR		LUMINARY 1C	DOCUMENT NO. FC-3900
ANALST			
DOCMR W. Dughit	9/20/69		
APPR'D R.M. Eaton	11/25/69	REV	SHEET 12 OF 46



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		Lunar Landing	
PRGMR		LUMINARY 1C	DOCUMENT NO. FC-3900
ANALST			
DOCMR W Daybach	9/24/69		
APPR'D Ryan Eaton	10/6/69	REV	SHEET 13 OF 46

From Preceding Sheet

$MPAC \leftarrow 2\,BUF^2 + BUF$
$PL26 \leftarrow 3\,BUF^2 + BUF$
$PL28 \leftarrow 4\,BUF^2 + 3\,BUF$
$PL30 \leftarrow 6\,BUF^2 + 6\,BUF + 1$

} Store in PUSHLIST

INTPRETX
Load X1 with index for target parameters
Sh. 35

$$MPAC_V \leftarrow \left[\frac{PL26_D \frac{RDG_V^{\#}X1 - RGU_V}{4(TTF/8_D)} + PL28_D(VDG_V^{\#}X1) + MPAC_D(VGU_V)}{TTF/8_D} + PL30_D(ADG_V^{\#}X1)\right]^{3/4}$$

AFCCALC1

$$UNFC/2_V \leftarrow MPAC_V \times CG_M - \frac{GDT/2_V}{GSCALE_D}$$

AFCCALC2

$$|AFC|_D \leftarrow |UNFC/2_V|$$

$$MPAC_D \leftarrow \left(\frac{HIGHESTF_D}{MASS_D}\right)^2 - (UNFC/2+2_D)^2 - (UNFC/2_D)^2$$

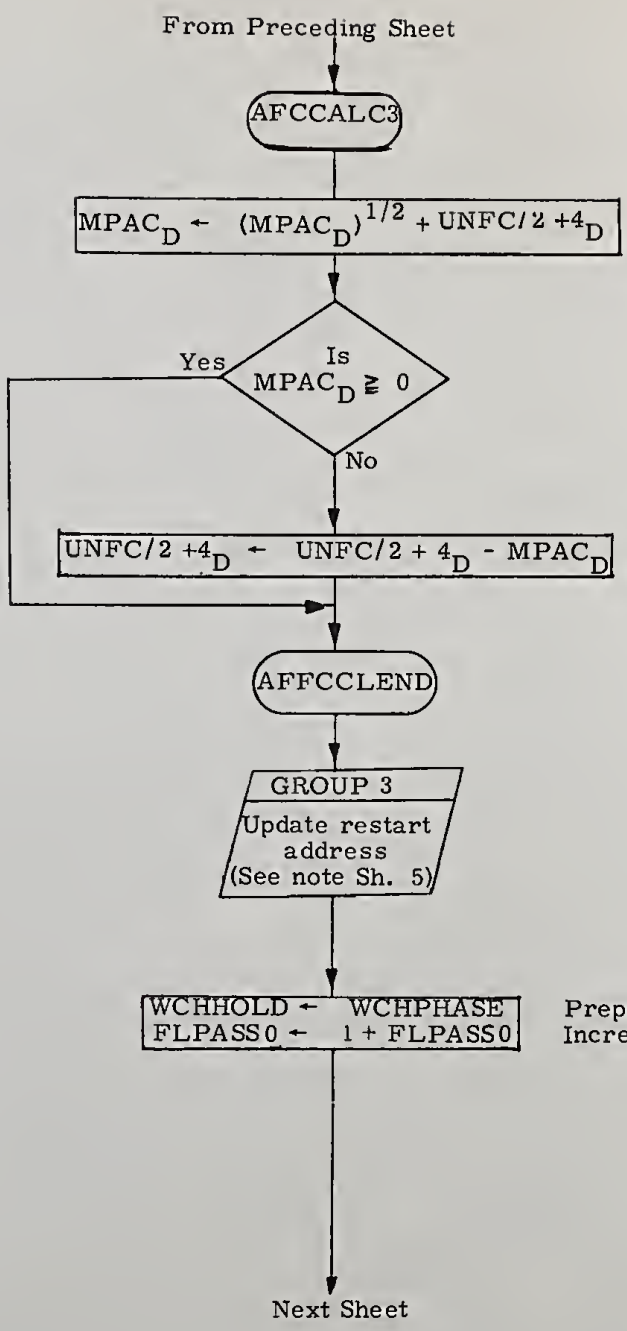
Is $MPAC_D \geq 0$?

No

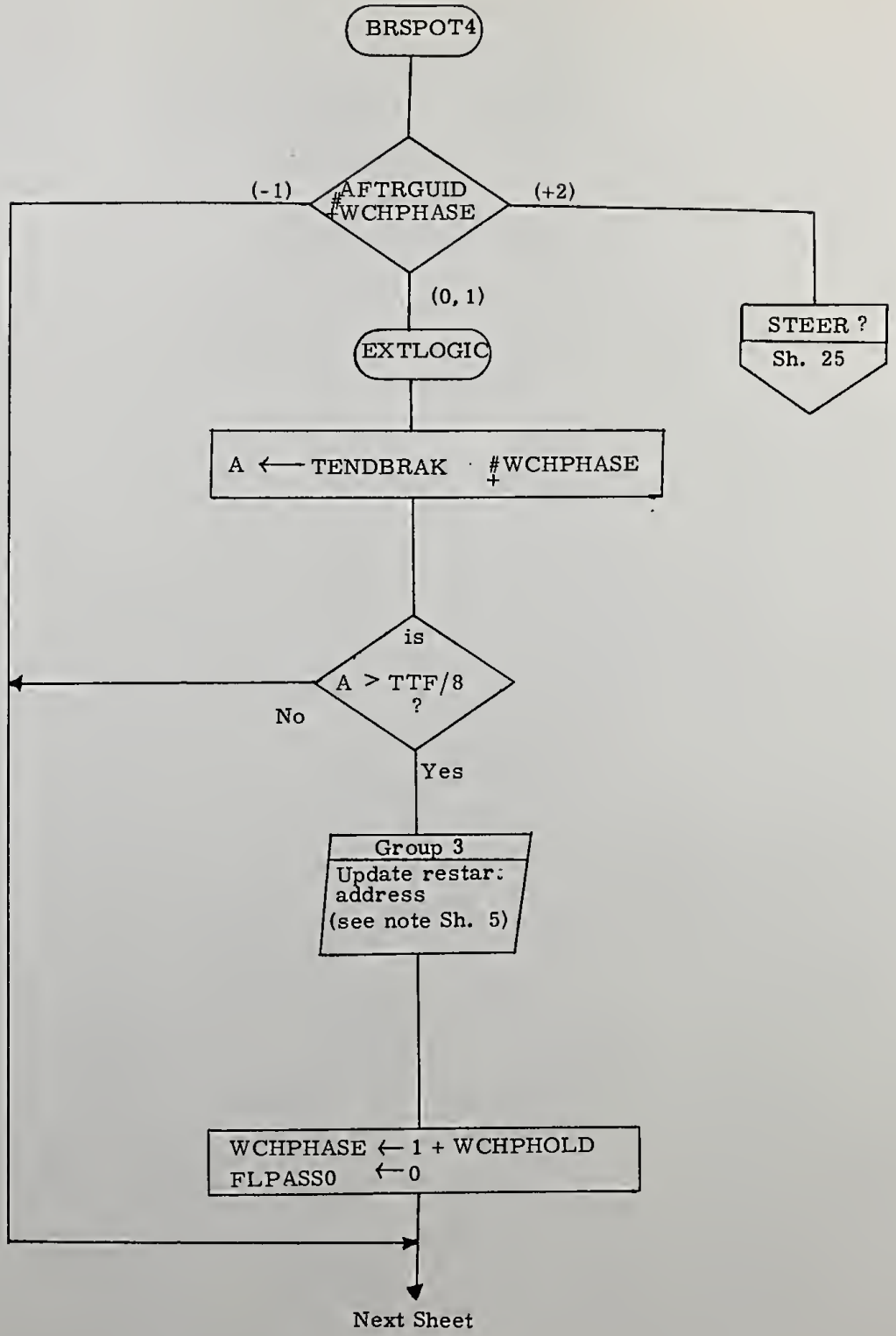
$MPAC_D \leftarrow 0$

Yes

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION
DRAWN		Lunar Landing
PRGMR		
ANALST		LUMINARY 1C — DOCUMENT NO. FC-3900
DOCMR	2/24/69	
APPR'D	3/5/69	REV — SHEET 140F 46

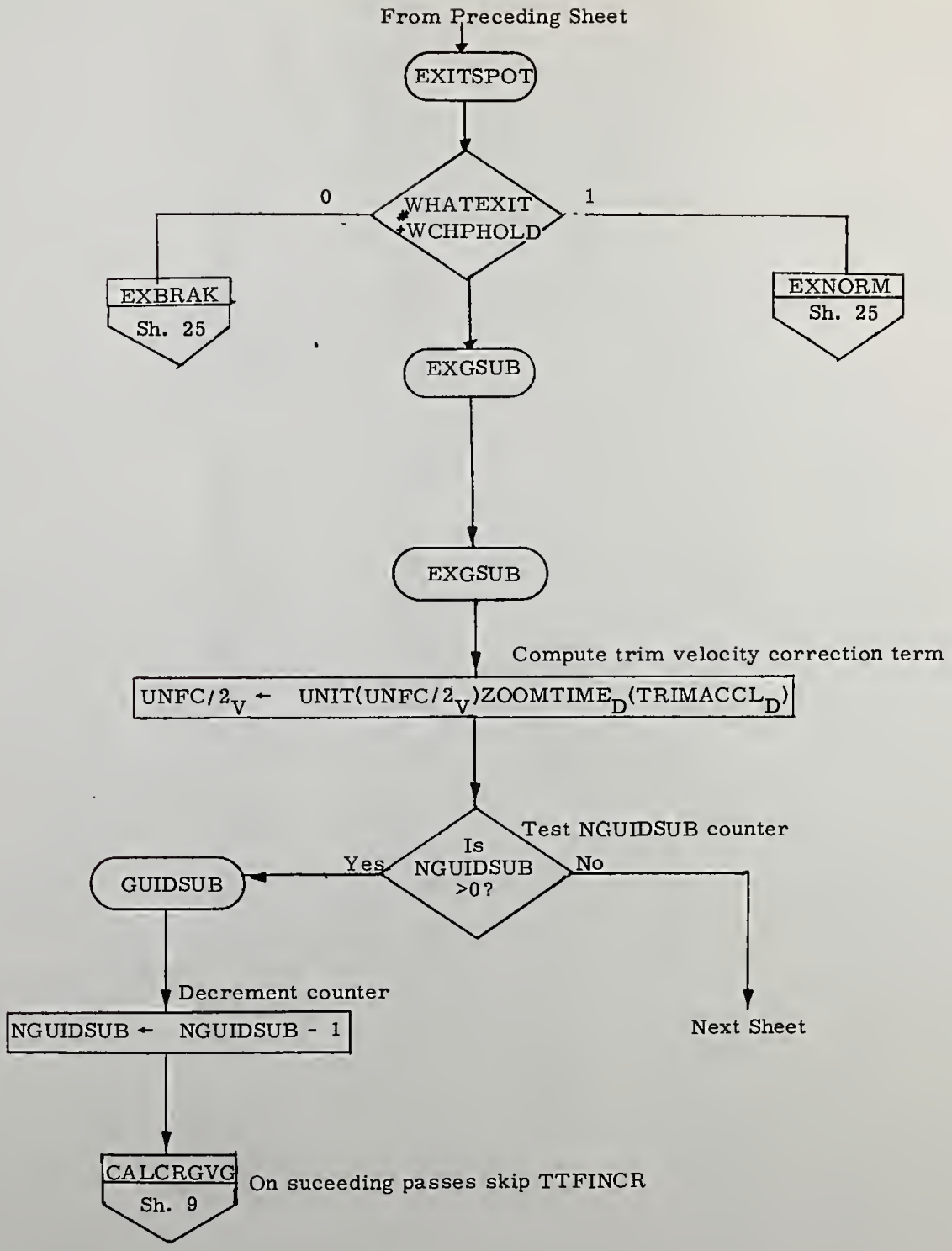


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		Lunar Landing	
PRGMR			
ANALST		LUMINARY 1C	DOCUMENT NO.
DOCMR	9/30/69		
APPR'D	11/5/69	REV	SHEET 15 OF 46

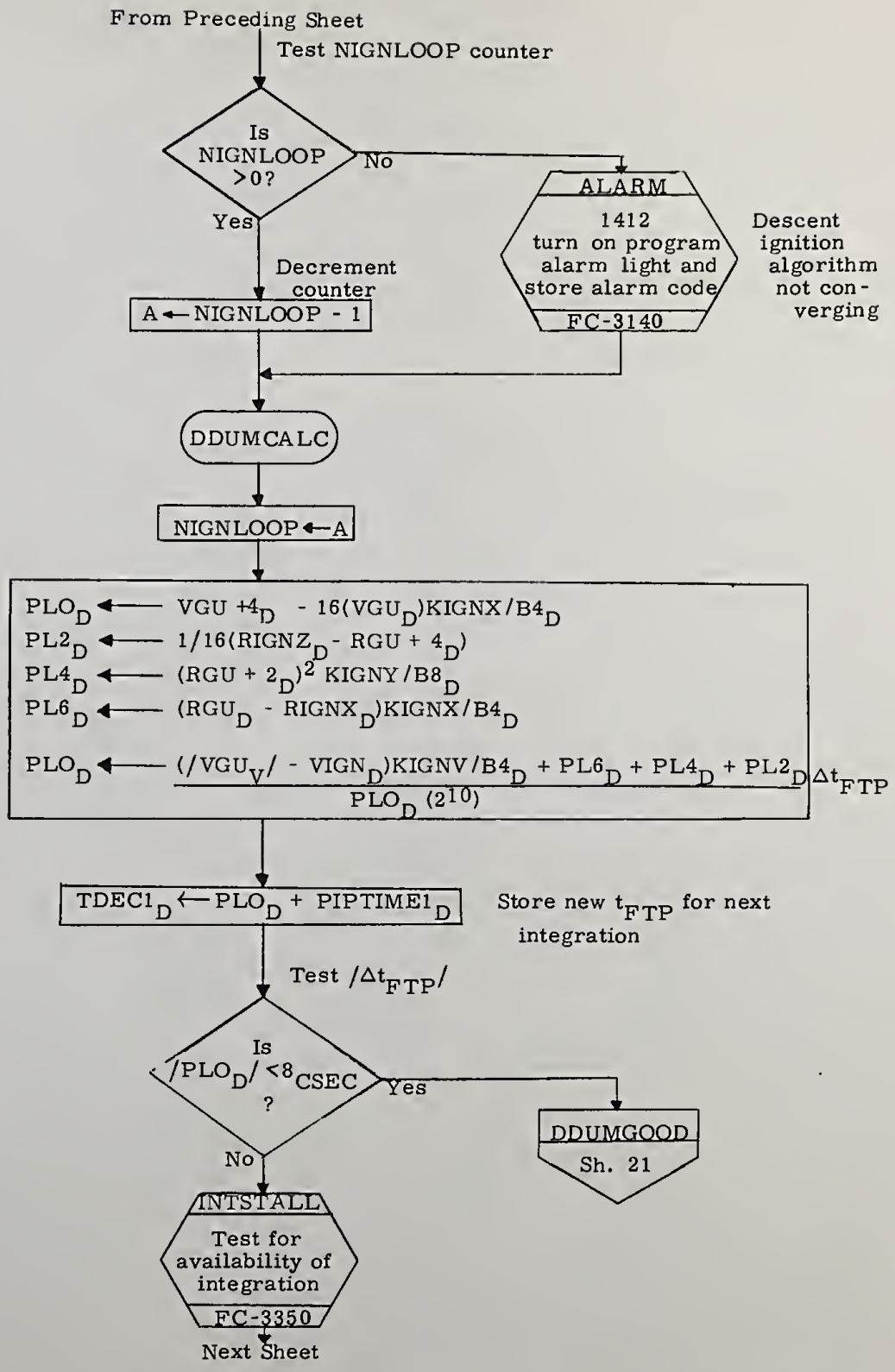


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		Lunar Landing	
PRGMR		LUMINARY 1C	DOCUMENT NO. FC-3900
ANALST			
DOCMR W Dapfrich	9/30/69		
APPR'D RM Eyles	11/5/69	REV	SHEET 18 OF 46

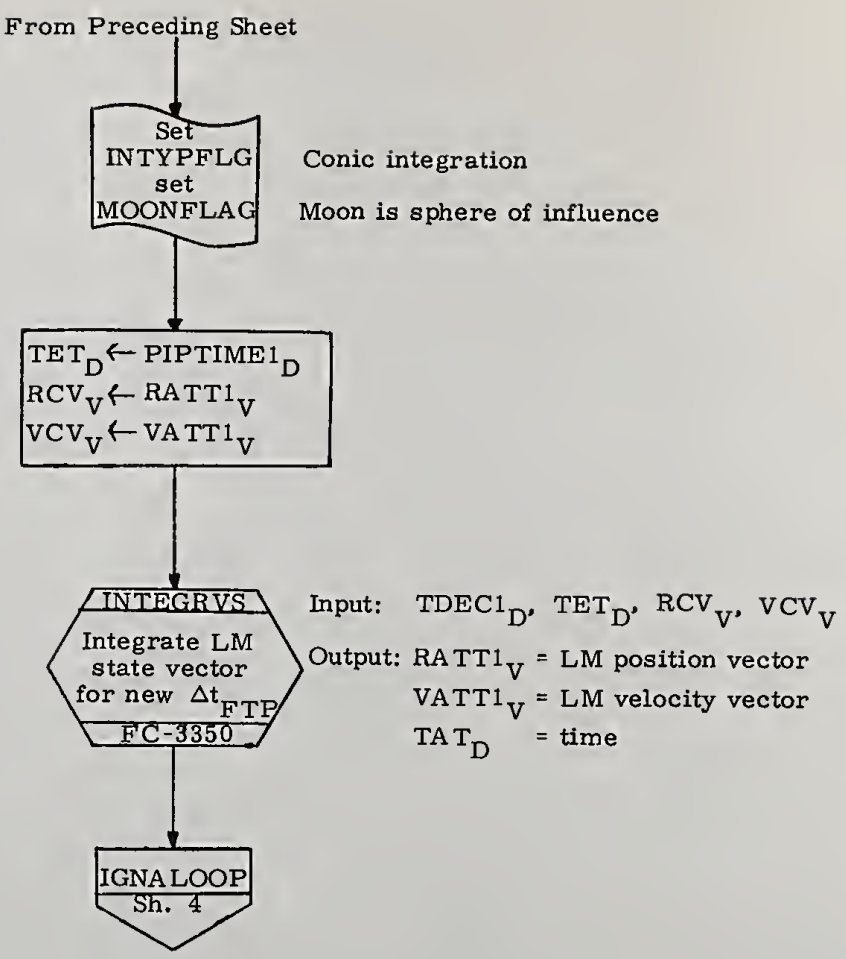
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		Lunar Landing	
PRGMR			
ANALST		LUMINARY 1C	DOCUMENT NO. FC-3900
DOCMR	7/29/69		
APPR'D	11/15/67	REV	SHEET 17 OF 46



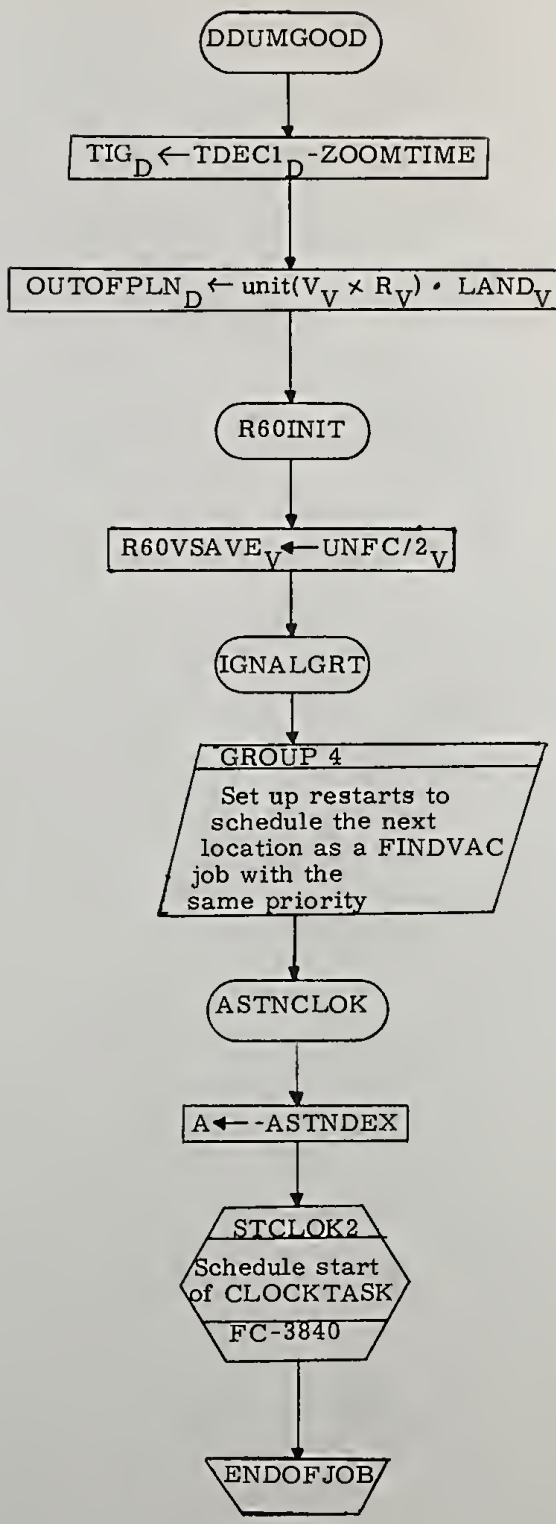
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		Lunar Landing	
PRGMR			
ANALST		LUMINARY 1C	DOCUMENT NO. FC-3900
DOCMR	2/24/69		
APPR'D	11/25/69	REV	SHEET 18 OF 46



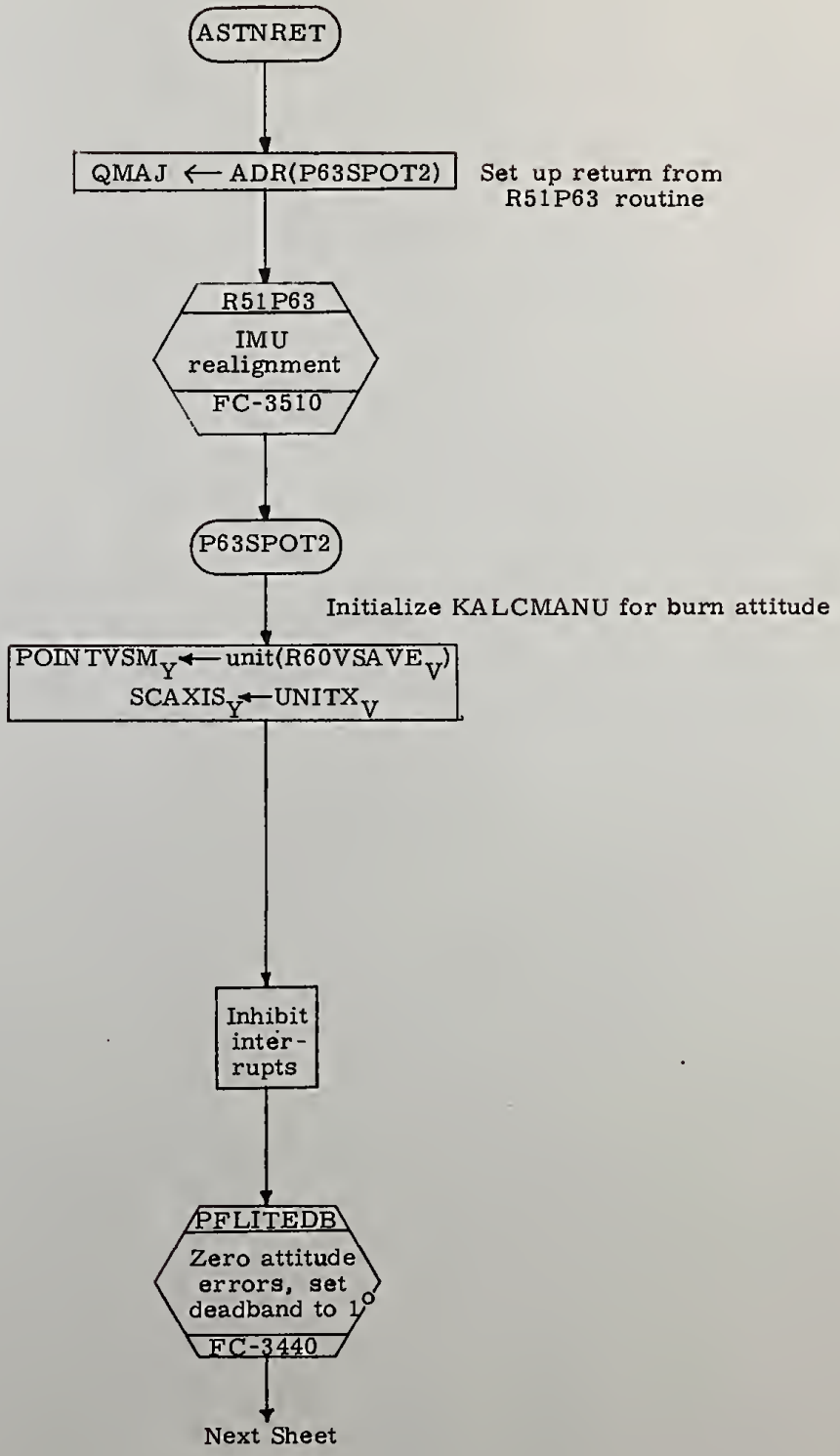
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		Lunar Landing	
PRGMR		LUMINARY 1C	DOCUMENT NO. FC-3900
ANALST			
DOCMR	9/30/69		
APPR'D	11/25/69	REV	SHEET 19 OF 46



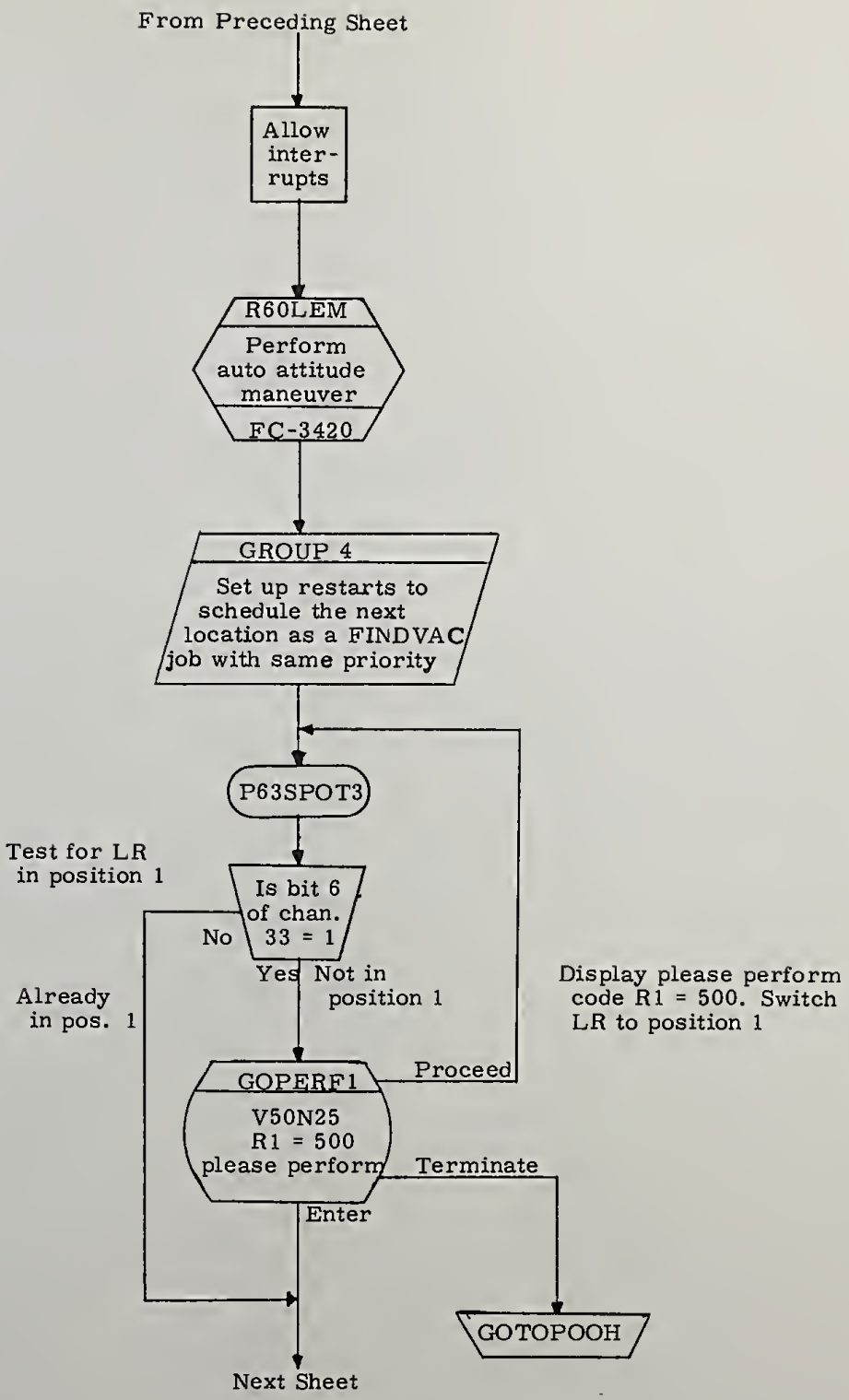
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		Lunar Landing	
PRGMR			
ANALST		LUMINARY 1C	DOCUMENT NO. FC-3900
DOCMR	4/24/69		
APPR'D	11/6/69	REV	SHEET 10 OF 46



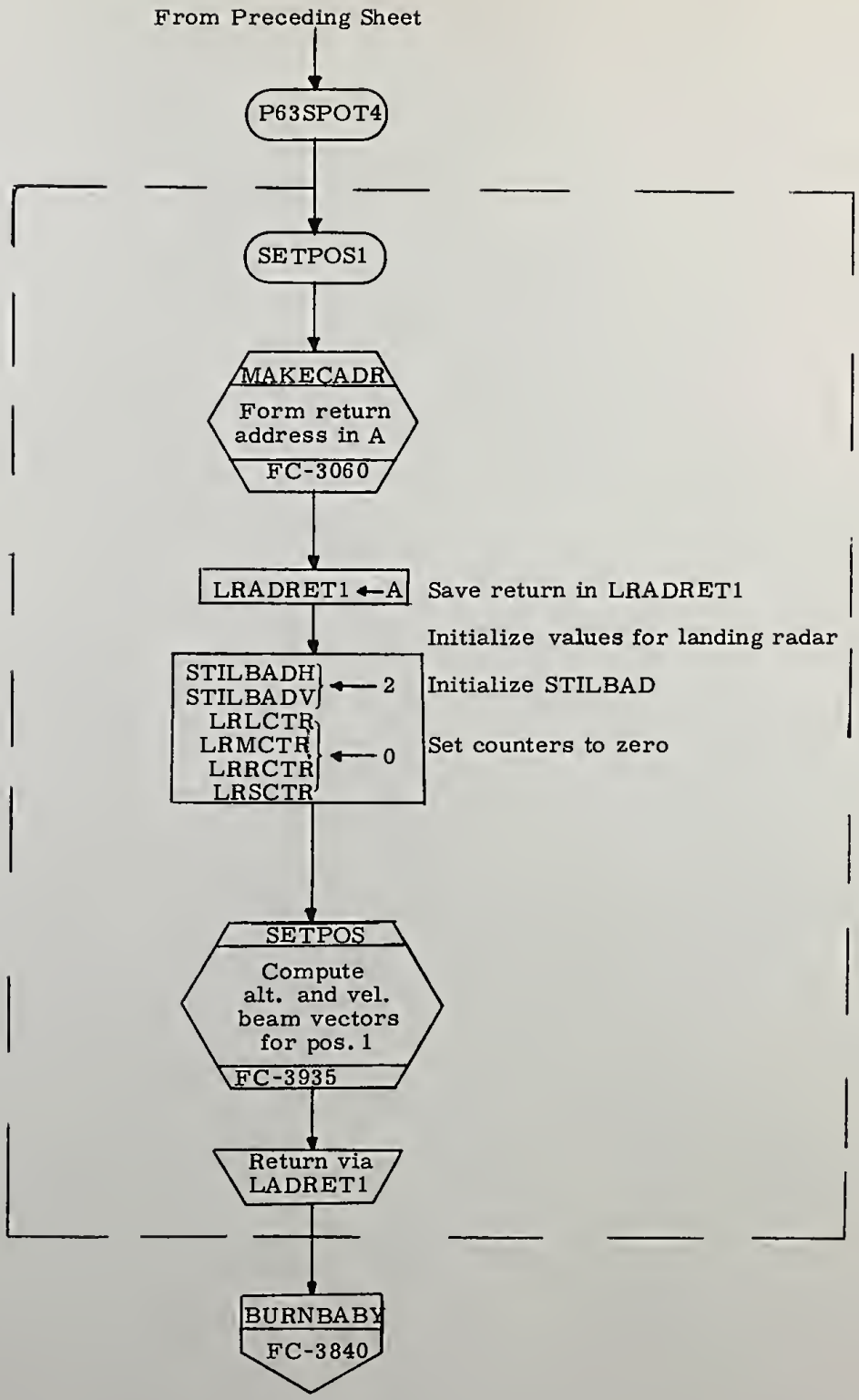
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		Lunar Landing	
PRGMR			
ANALST		LUMINARY 1C	DOCUMENT NO. FC-3900
DOCMR	9/29/69	REV	SHEET 21 OF 46
APPR'D	11/25/67		



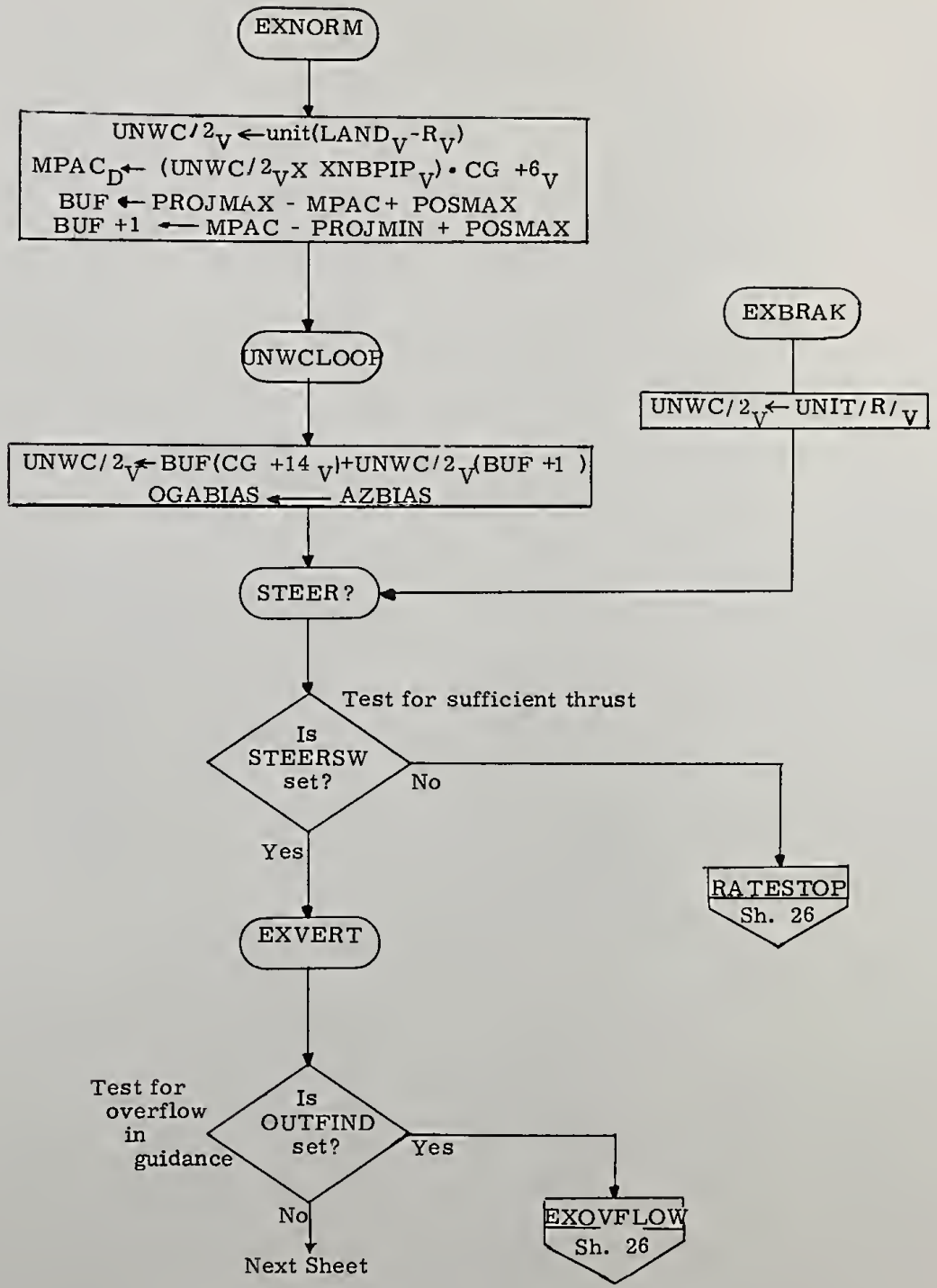
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		Lunar Landing	
PRGMR		LUMINARY 1C	DOCUMENT NO. FC-3900
ANALST			
DOCMR	9/29/69	REV	SHEET 22 OF 48
APPR'D	11/25/69		



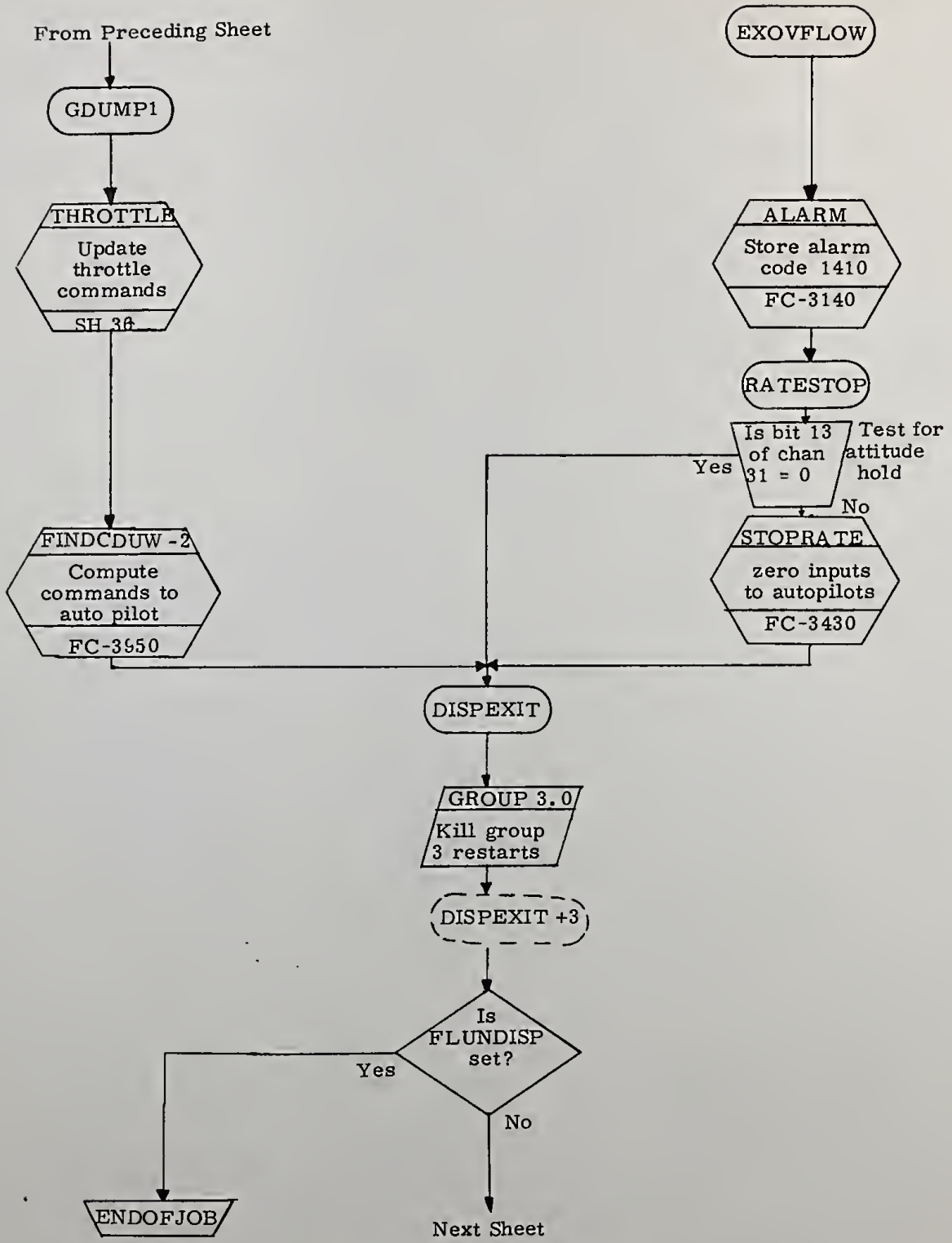
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		Lunar Landing	
PRGMR		LUMINARY 1C	DOCUMENT NO. FC-3900
ANALST			
DOCMR	9/30/69	REV	SHEET 28 OF 46
APPR'D	11/25/69		



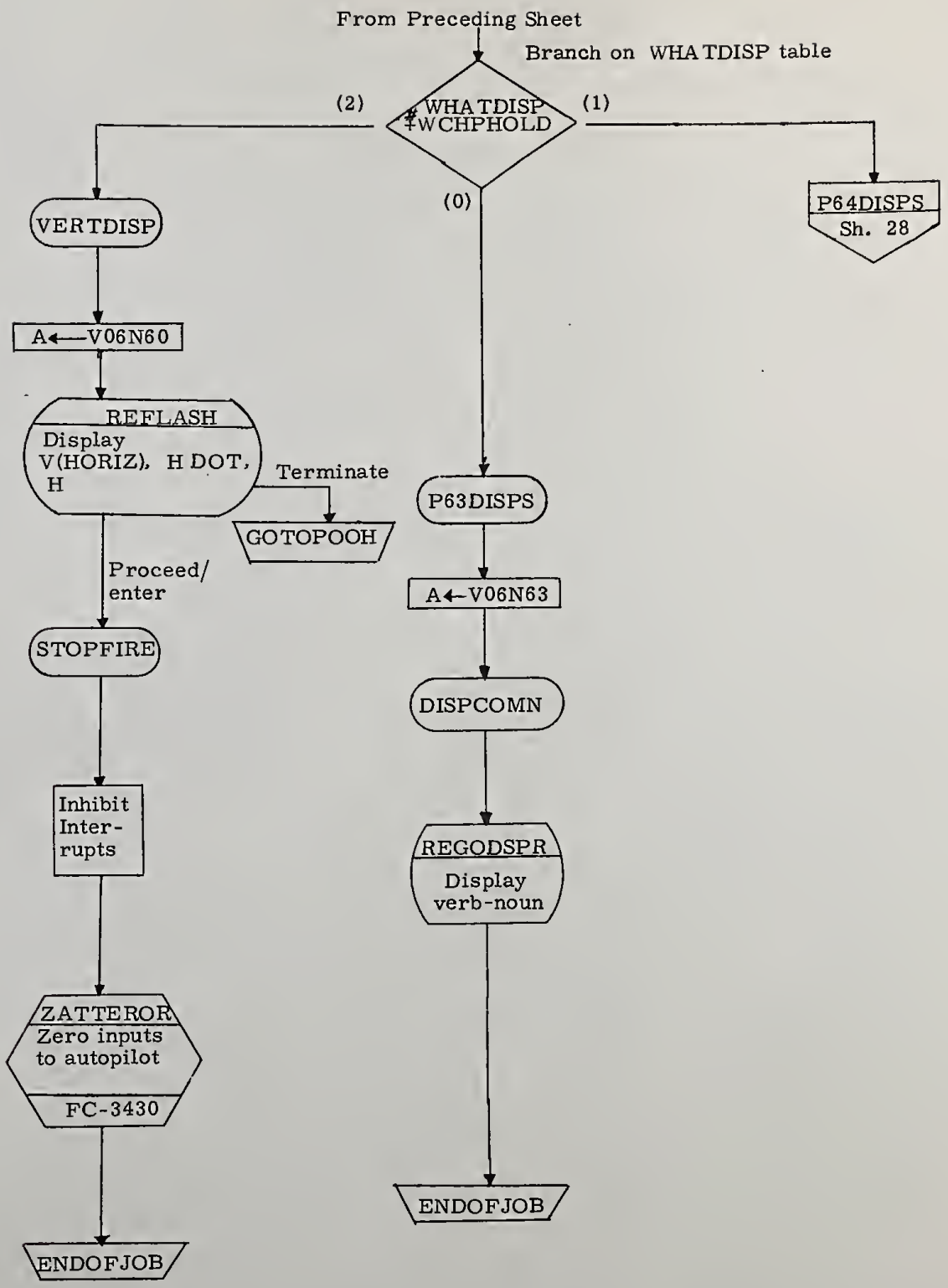
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		Lunar Landing	
PRGMR			
ANALST		LUMINARY 1C	DOCUMENT NO. FC-3900
DOCMR	9/30/69		
APPR'D	11/25/69	REV	SHEET 24 OF 56



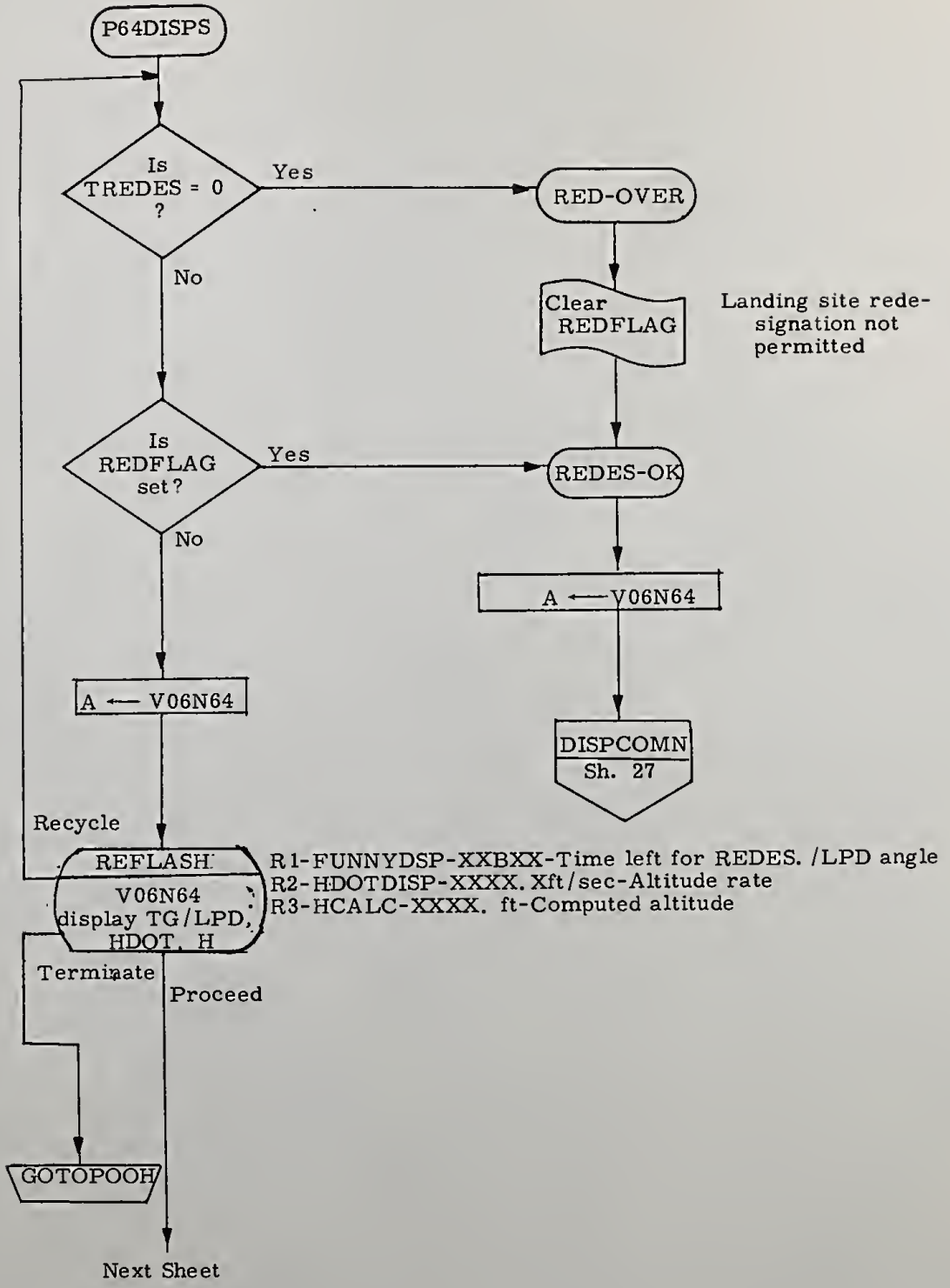
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		Lunar Landing	
PRGMR			
ANALST		LUMINARY 1C	DOCUMENT NO. FC-3900
DOCMR	9/30/69		
APPR'D	11/25/69	REV	SHEET 45 OF 46



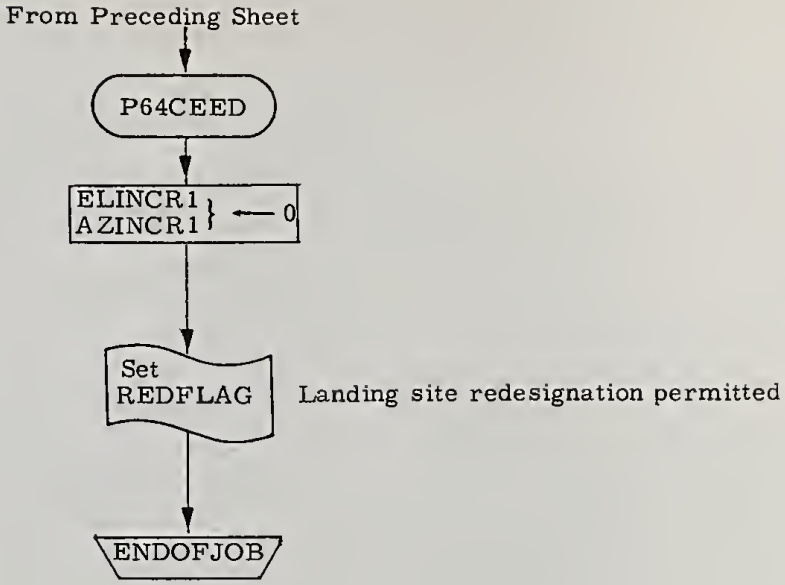
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		Lunar Landing	
PRGMR		LUMINARY 1C	DOCUMENT NO. FC-3900
ANALST			
DOCMR	9/24/69	REV	SHEET 28 OF 46
APPR'D	11/25/69		

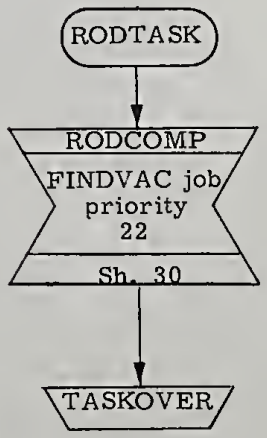


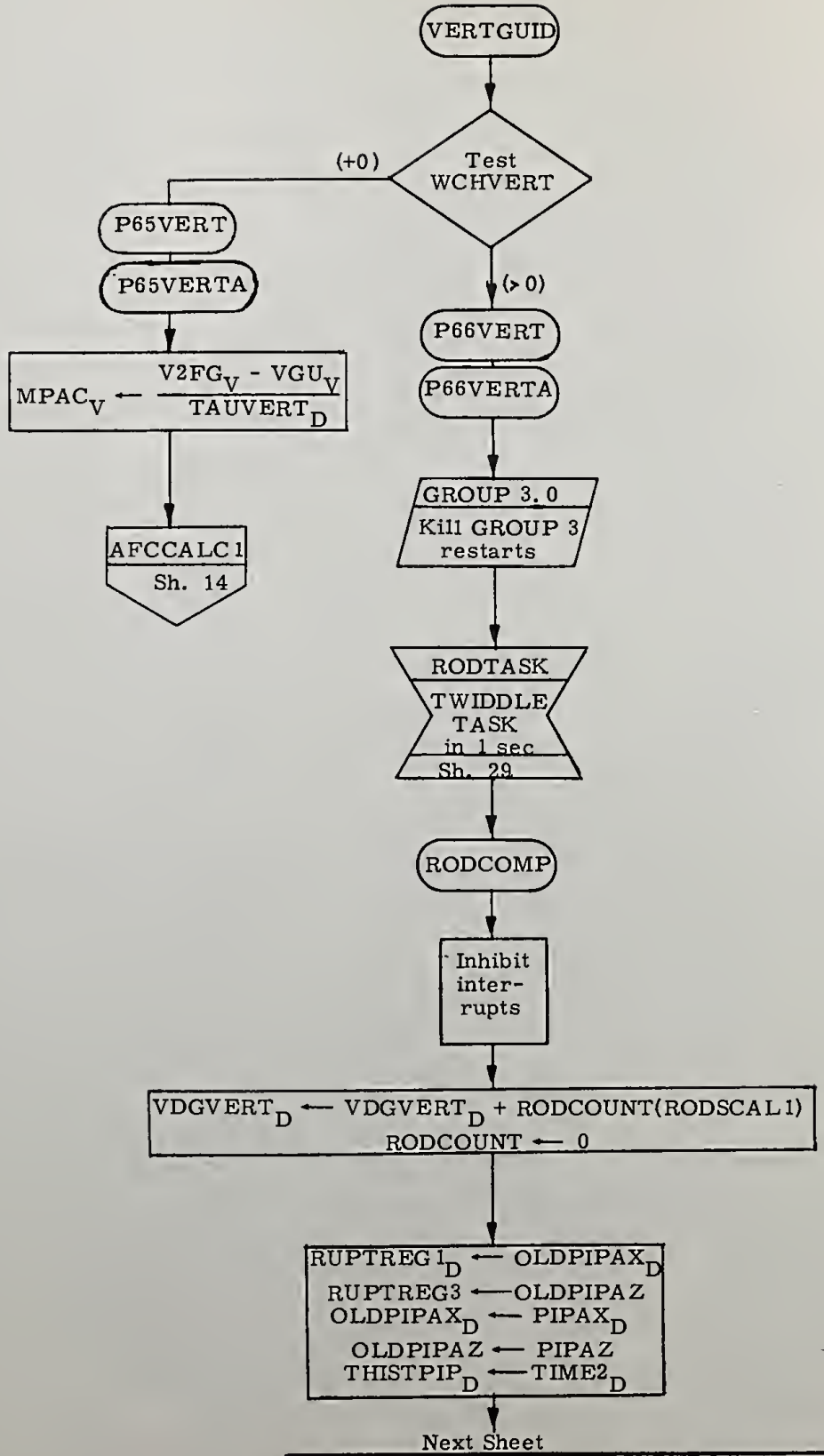
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		Lunar Landing	
PRGMR			
ANALST		LUMINARY 1C	DOCUMENT NO. FC-3900
DOCMR W Danforth	9/30/69		
APPR'D R M Eaton	11/25/69	REV	SHEET 270F 46



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		Lunar Landing	
PRGMR		LUMINARY 1C	DOCUMENT NO. FC-3900
ANALST			
DOCMR	12/9/69		
APPR'D	11/26/69	REV	SHEET 46 OF 46


From Preceding Sheet
P64CEED
ELINCR1
AZINCR1
0
Set
REDFLAG
Landing site redesignation permitted
ENDOFJOB


RODTASK
RODCOMP
FINDVAC job
priority
22
Sh. 30
TASKOVER



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		Lunar Landing	
PRGMR			
ANALST		PRELIMINARY 1C	DOCUMENT NO. FC-3900
DOCMR	9/24/69		
APPR'D	11/25/69	REV	SHEET 39 OF 46

From Preceding Sheet

$$\begin{aligned}
MPAC &\leftarrow OLDPIPAX + PIPATMPX \\
MPAC\ +1 &\leftarrow 0 \\
MPAC\ +3 &\leftarrow OLDPIPAY + PIPATMPY \\
MPAC\ +4 &\leftarrow 0 \\
MPAC\ +5 &\leftarrow OLDPIPAZ + PIPATMPZ \\
MPAC\ +6 &\leftarrow 0
\end{aligned}$$

$$\begin{aligned}
DELVROD &\leftarrow TEMX + RUPTREG1 - OLDPIPAX \\
DELVROD\ +2 &\leftarrow TEMY + RUPTREG2 - OLDPIPAY \\
DELVROD\ +4 &\leftarrow TEMZ + RUPTREG3 - OLDPIPAZ
\end{aligned}$$

$$\begin{aligned}
TEMX &\leftarrow 0 \\
TEMY &\leftarrow 0 \\
TEMZ &\leftarrow 0
\end{aligned}$$

ITRPNT1

$$PL0_V \leftarrow MPAC_V(KPIP1_D)$$

$$PL30_D \leftarrow THISTPIP_D - PIPTIME_D$$

Time since PIPTIME

$$PL6_D \leftarrow \frac{PL30_D}{4SEC(28)}$$

$$PL24_V \leftarrow PL0_V + (GPT/2_V - VBIAS_V)PL6_D + V_V$$

Updated velocity

$$PL14_V \leftarrow UNIT(R_V)$$

$$HDOTDISP_D \leftarrow PL14_V \cdot PL24_V$$

$$HCALC1_D \leftarrow PL30_D(HDOTDISP_D) + |R_V| - |LAND|_D$$

$$PL0_V \leftarrow \frac{VDGVERT_D - HDOTDISP_D}{TAUROD_D}$$

$$PL20_D \leftarrow \frac{|GDT/2_V|}{GSCALE_D}$$

$$PL0_D \leftarrow PL0_D + PL20_D$$

$$MPAC_V \leftarrow UNITX_V$$

CDU*NBSM

Transform input vector from NB to SM coord.

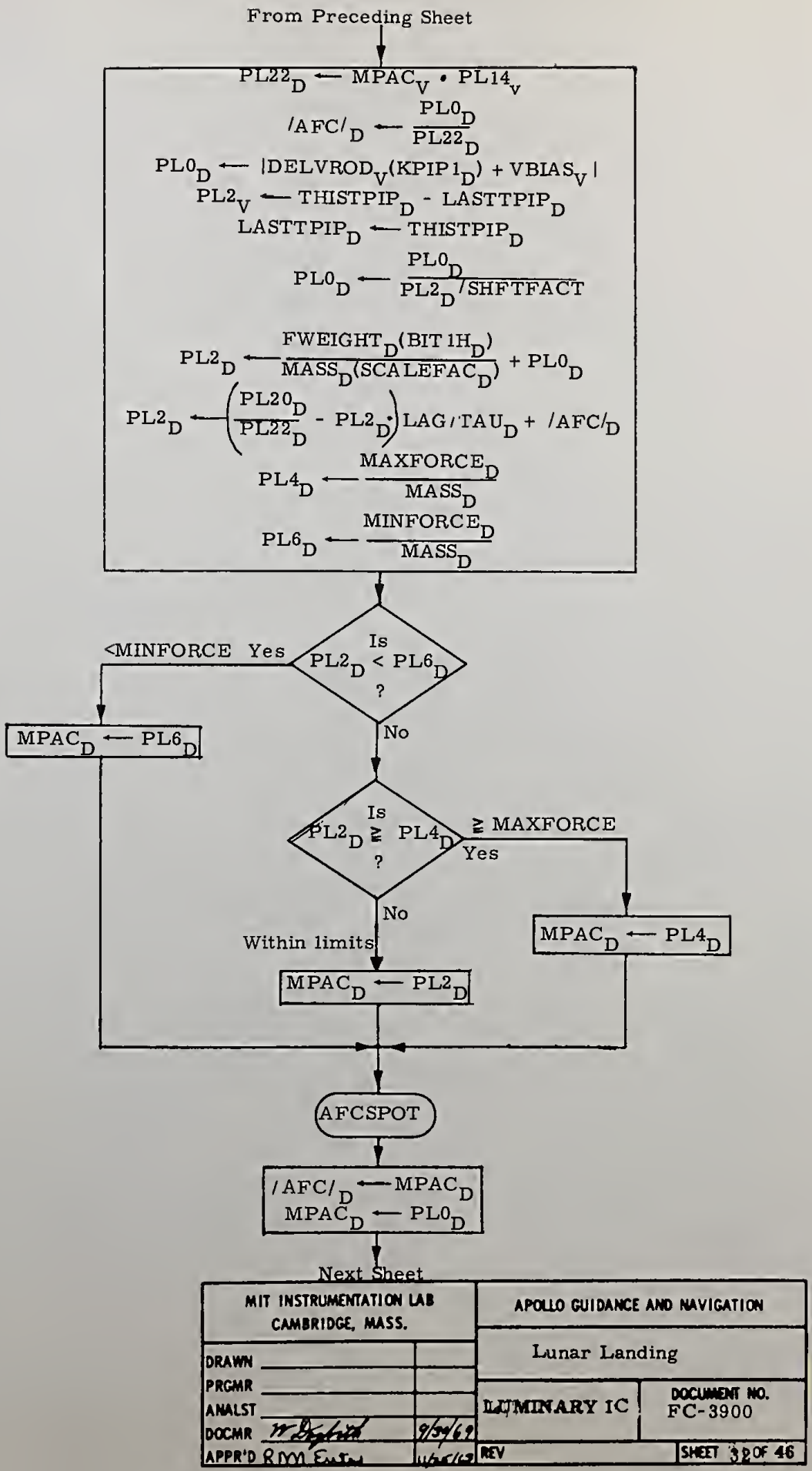
FC-3320

Input: $MPAC_V$ = input vector in NB coordinates

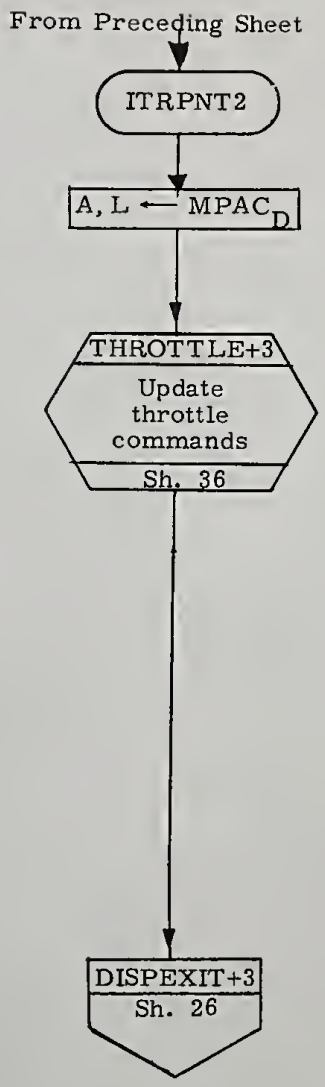
Output: $MPAC_V$ = transformed vector in SM coordinates

Next Sheet

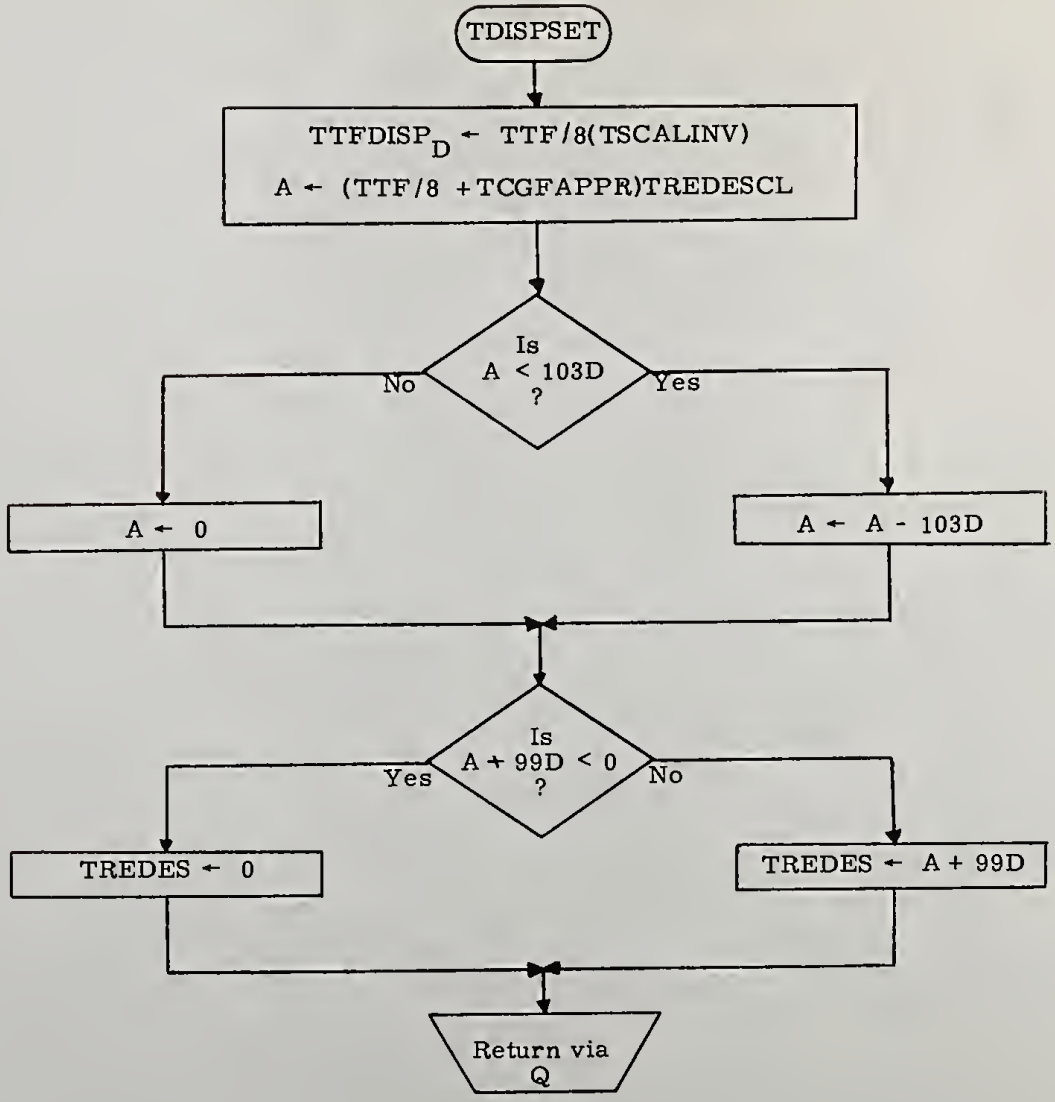
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		Lunar Landing	
PRGMR			
ANALST		LUMINARY 1C	DOCUMENT NO. FC-3900
DOCMR	8/30/69		
APPR'D	11/25/69	REV	SHEET 31 OF 46



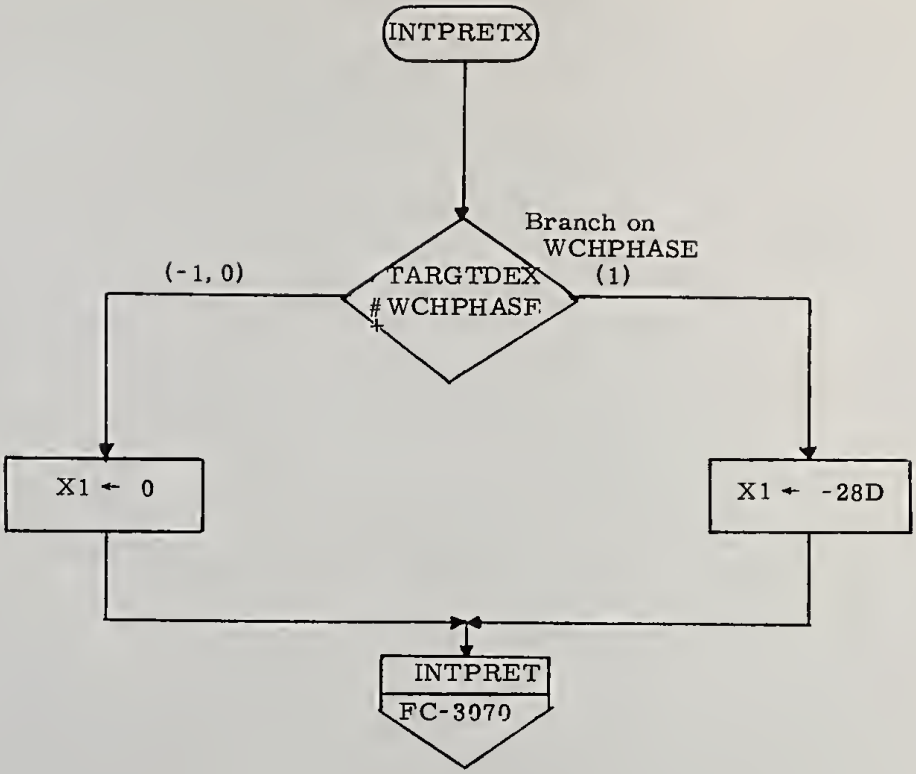
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		Lunar Landing	
DRAWN		LUMINARY IC	DOCUMENT NO. FC-3900
PRGMR			
ANALST			
DOCMR	9/24/69	REV	SHEET 32 OF 46
APPR'D	11/25/69		



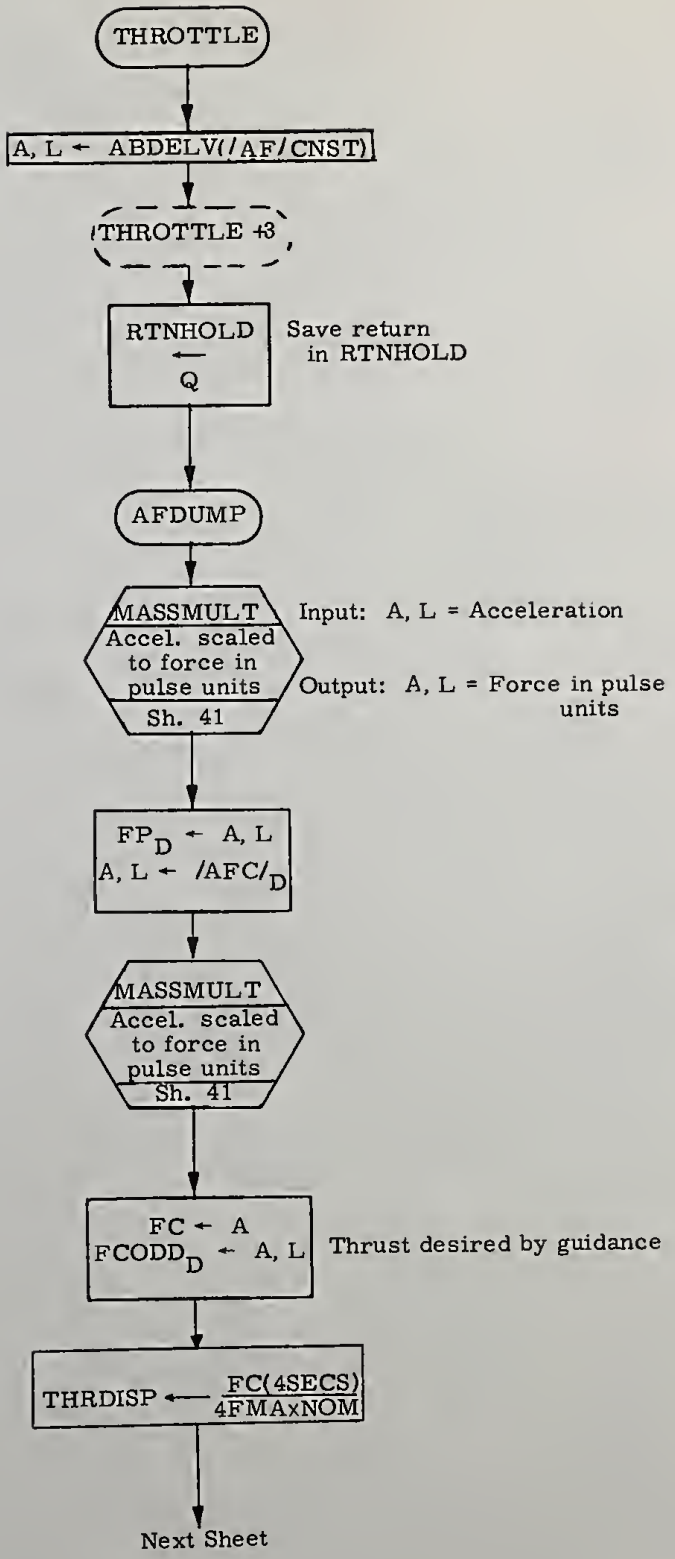
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		Lunar Landing	
PRGMR			
ANALST		LUMINARY 1C	DOCUMENT NO. FC-3900
DOCMR	9/30/69		
APPR'D	11/25/69	REV	SHEET 33 OF 46



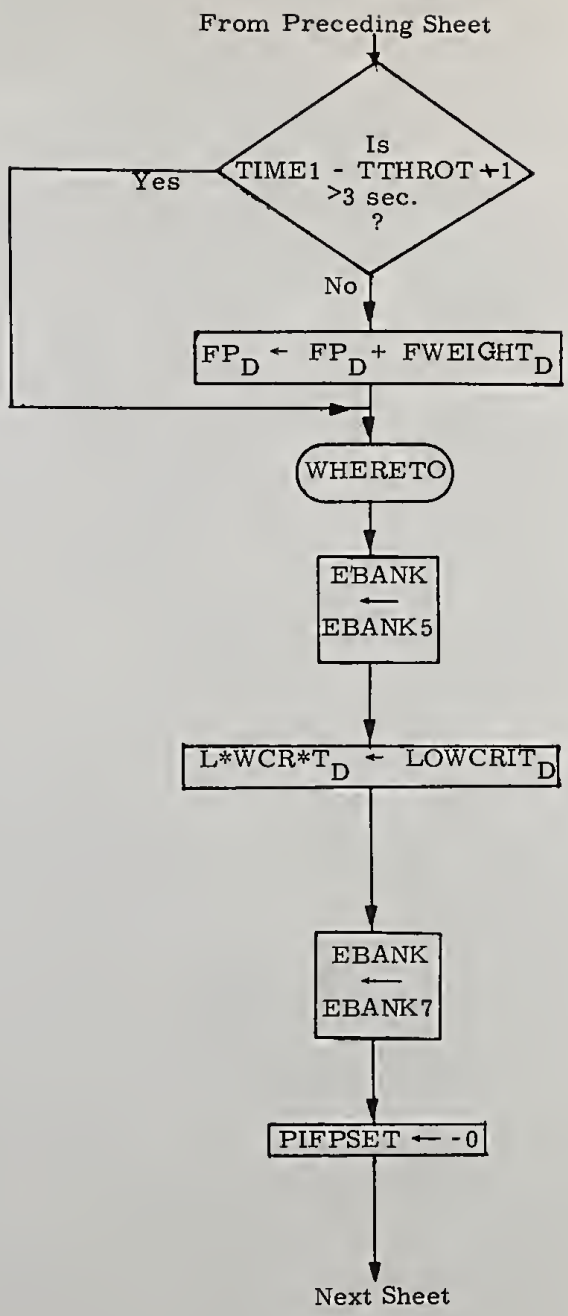
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		Lunar Landing	
PRGMR			
ANALST		LUMINARY/1C	DOCUMENT NO. FC-3900
DOCMR	9/30/69		
APPR'D	11/6/69	REV	SHEET 34 OF 48



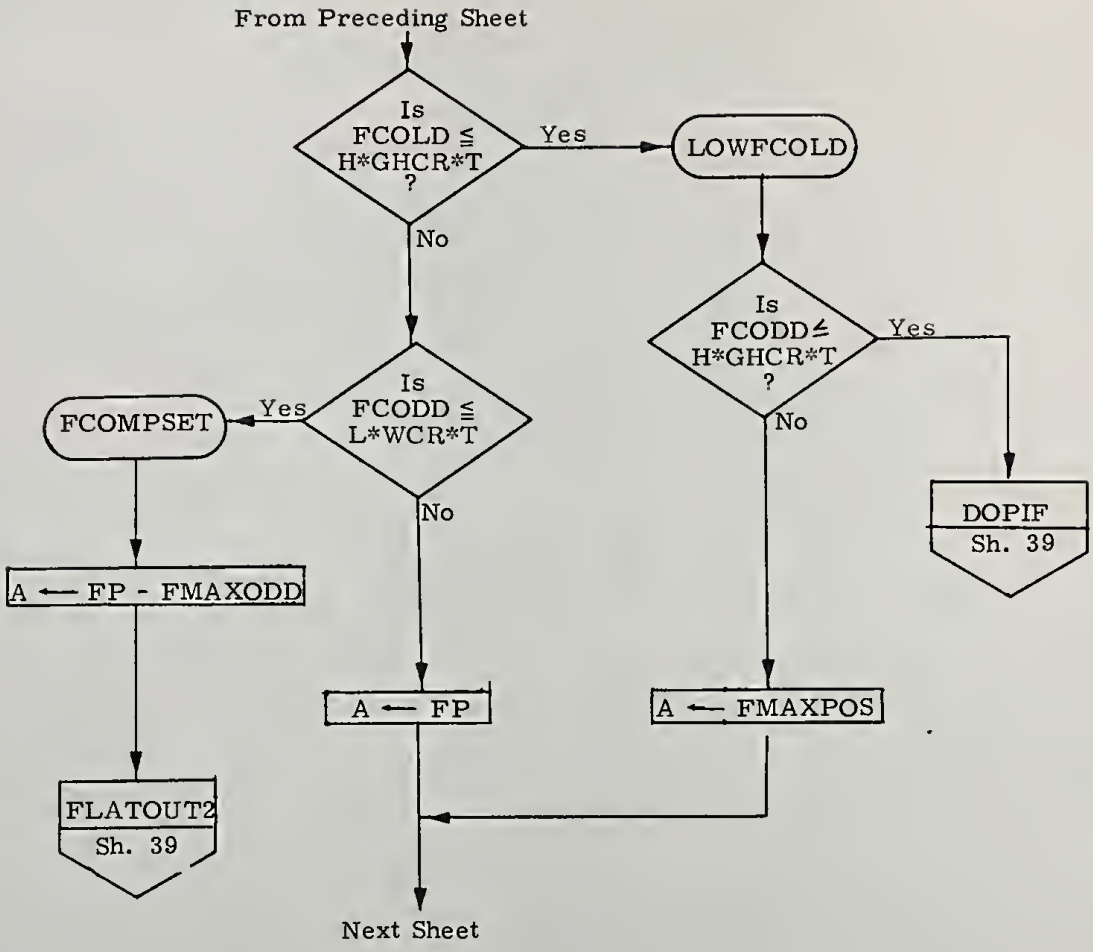
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		Lunar Landin g	
PRGMR			
ANALST		'LUMINARY 1C	DOCUMENT NO. FC-3000
DOCMR W Sybrook	9/09/69		
APPR'D R M Eaton	11/26/69	REV	SHEET 35 OF 46



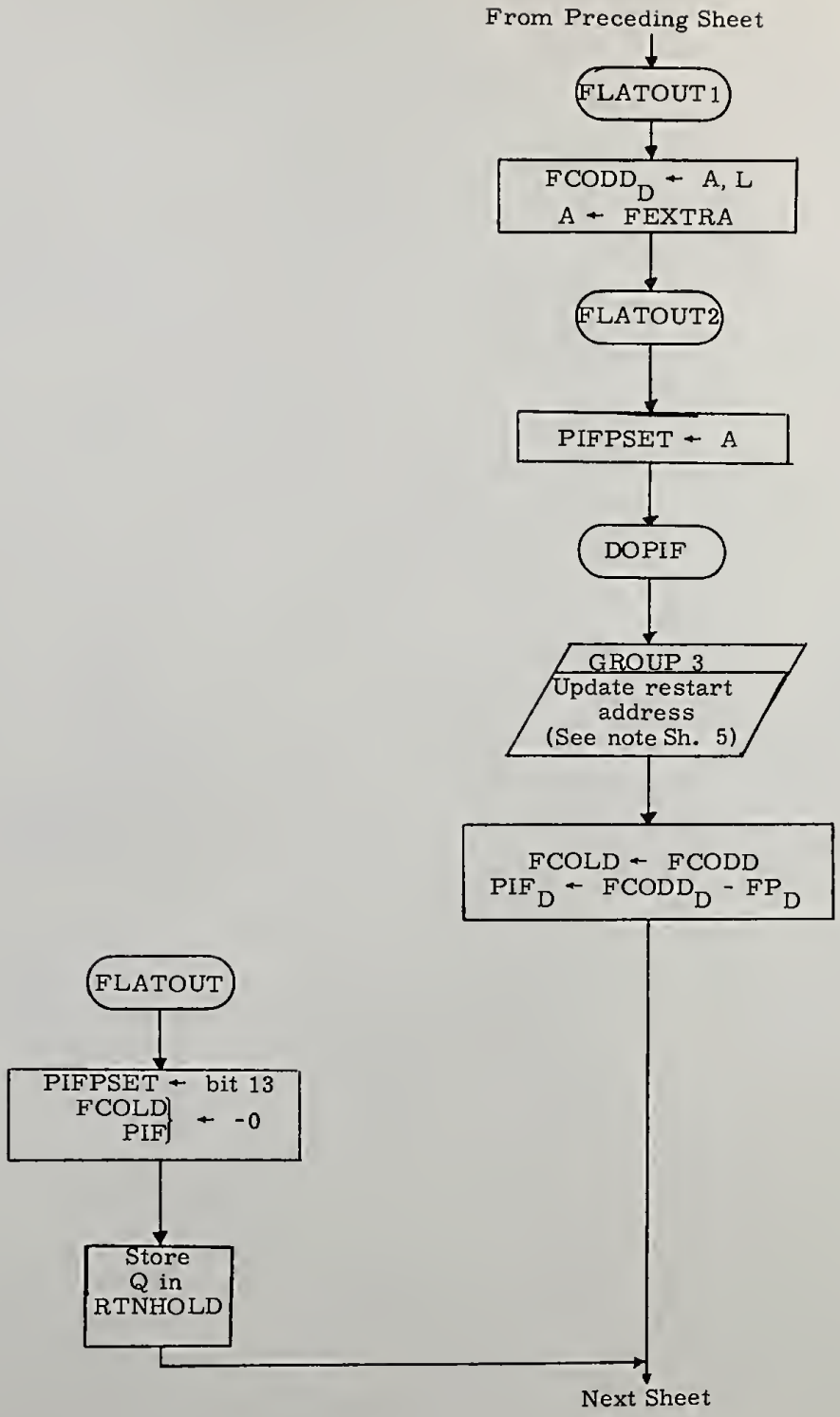
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
		Lunar Landing	
DRAWN		LUMINARY 1C	DOCUMENT NO. FC-3900
PRGMR			
ANALST			
DOCMR W Bamforth	9/30/69		
APPR'D R.M.M. Eustis	10/2/69	REV	SHEET 36 OF 46



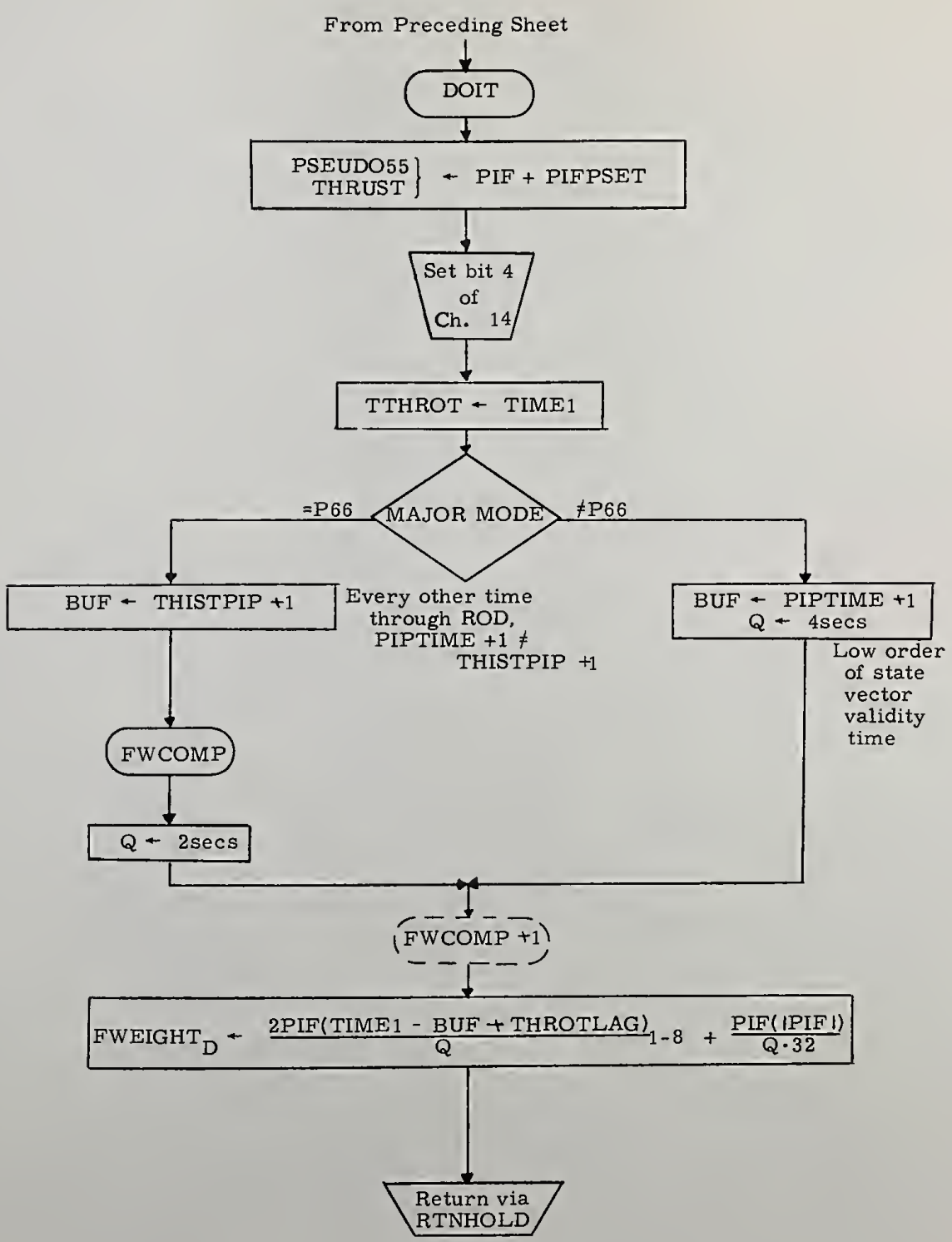
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		Lunar Landing	
PRGMR			
ANALST		LUMINARY 1C	DOCUMENT NO. FC-3900
DOCMR	M Dighton 9/30/69		
APPR'D	R M Eaton 11/25/69	REV	SHEET 37 OF 46



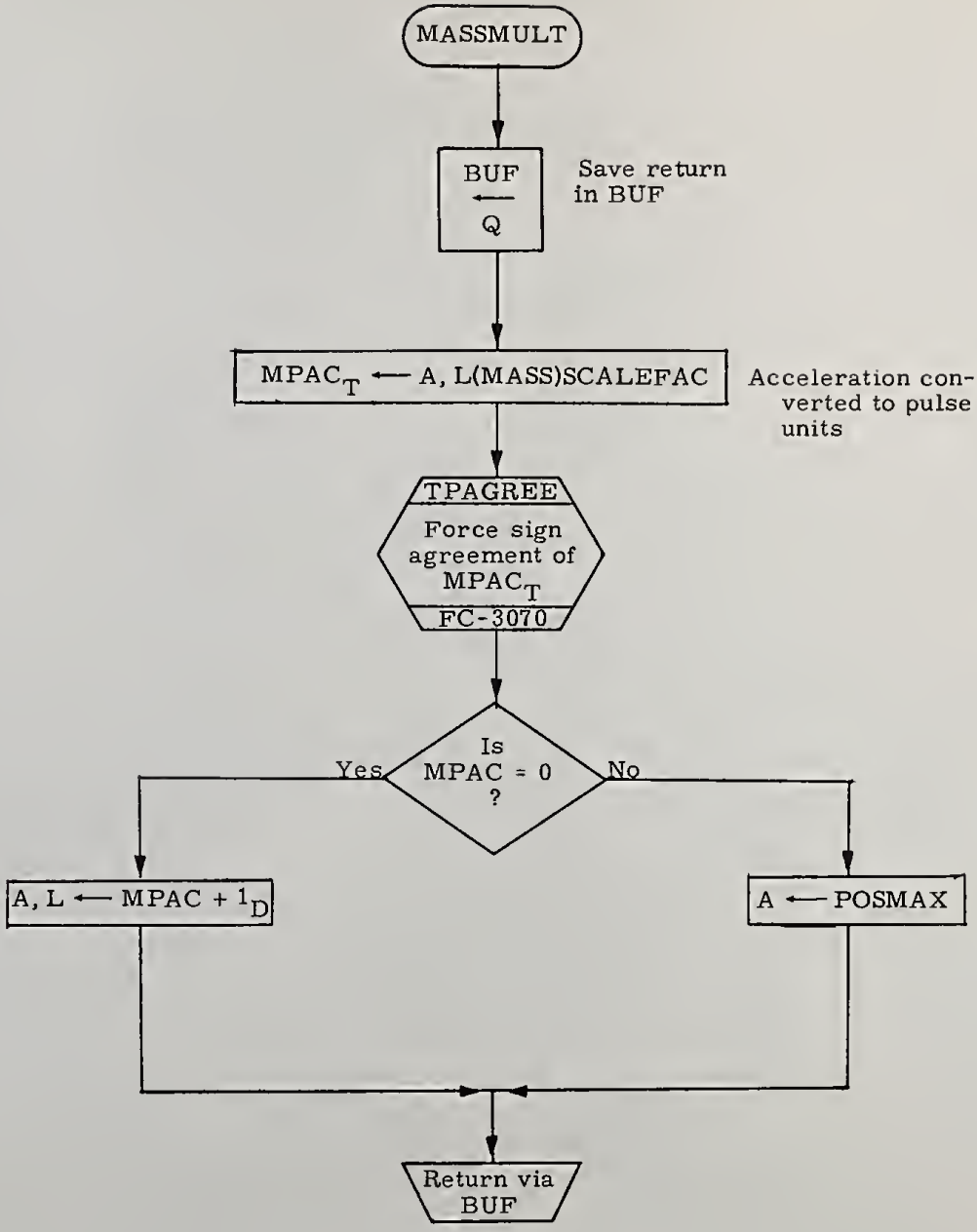
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		Lunar Landing	
PRGMR			
ANALST		LUMINARY 1C	DOCUMENT NO. FC-3900
DOCMR	9/24/69		
APPR'D	11/25/69	REV	SHEET 38 OF 46



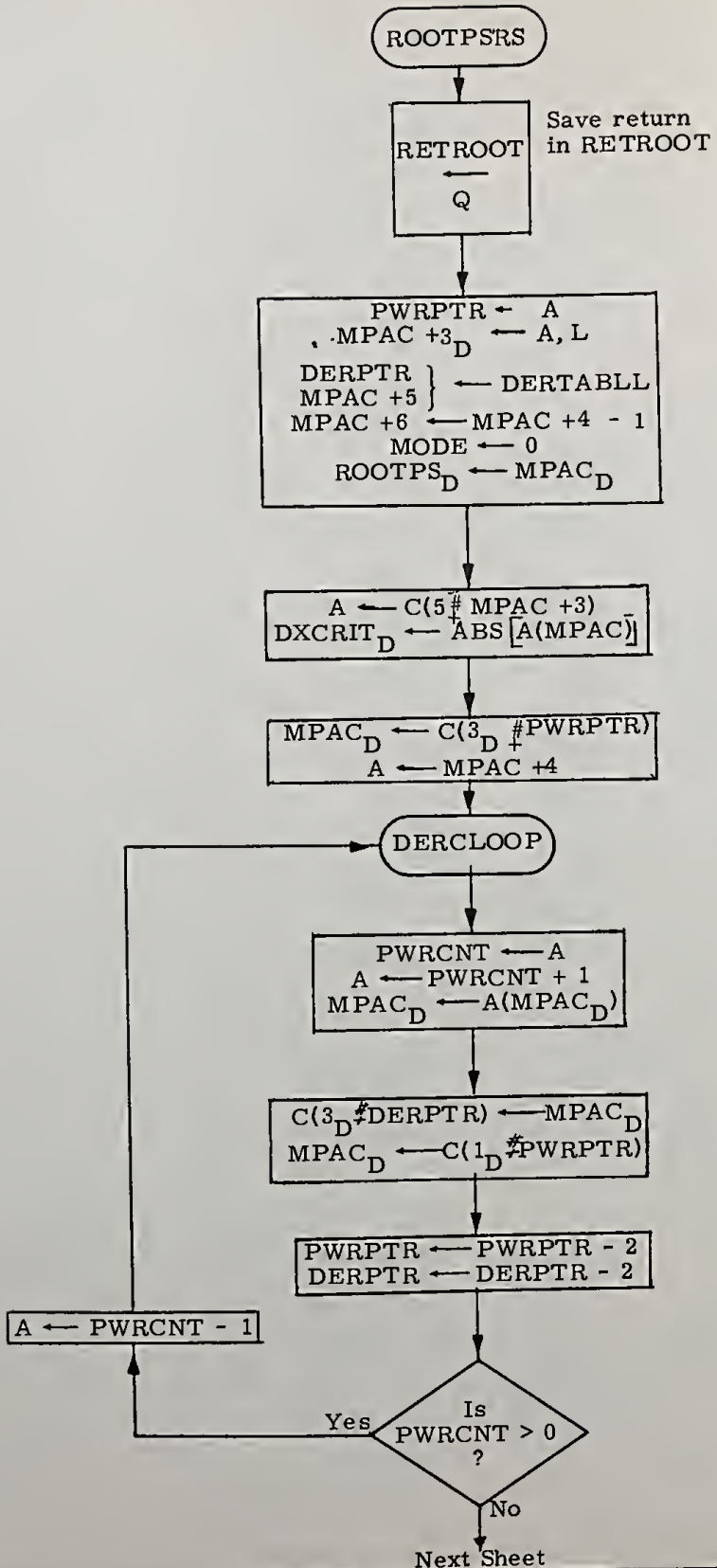
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		Lunar Landing	
PRGMR			
ANALST		LUMINARY 1C	DOCUMENT NO. FC-3900
DOCMR	9/30/69		
APPR'D	11/26/69	REV	SHEET 39 OF 46



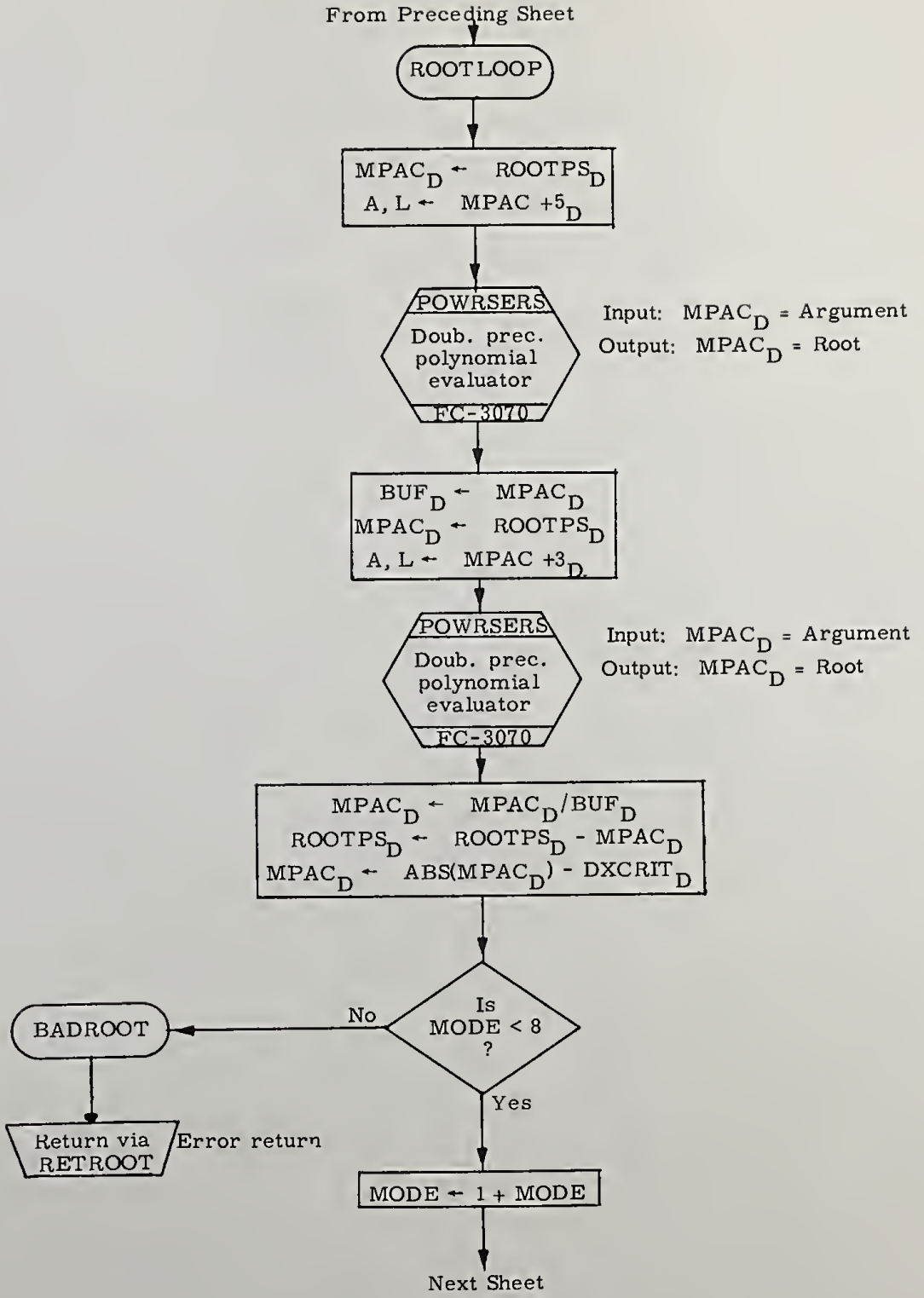
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		Lunar Landing	
PRGMR			
ANALST		LUMINARY 1C	DOCUMENT NO. FC-3900
DOCMR	7/24/69	REV	SHEET 40 OF 46
APPR'D	7/25/69		



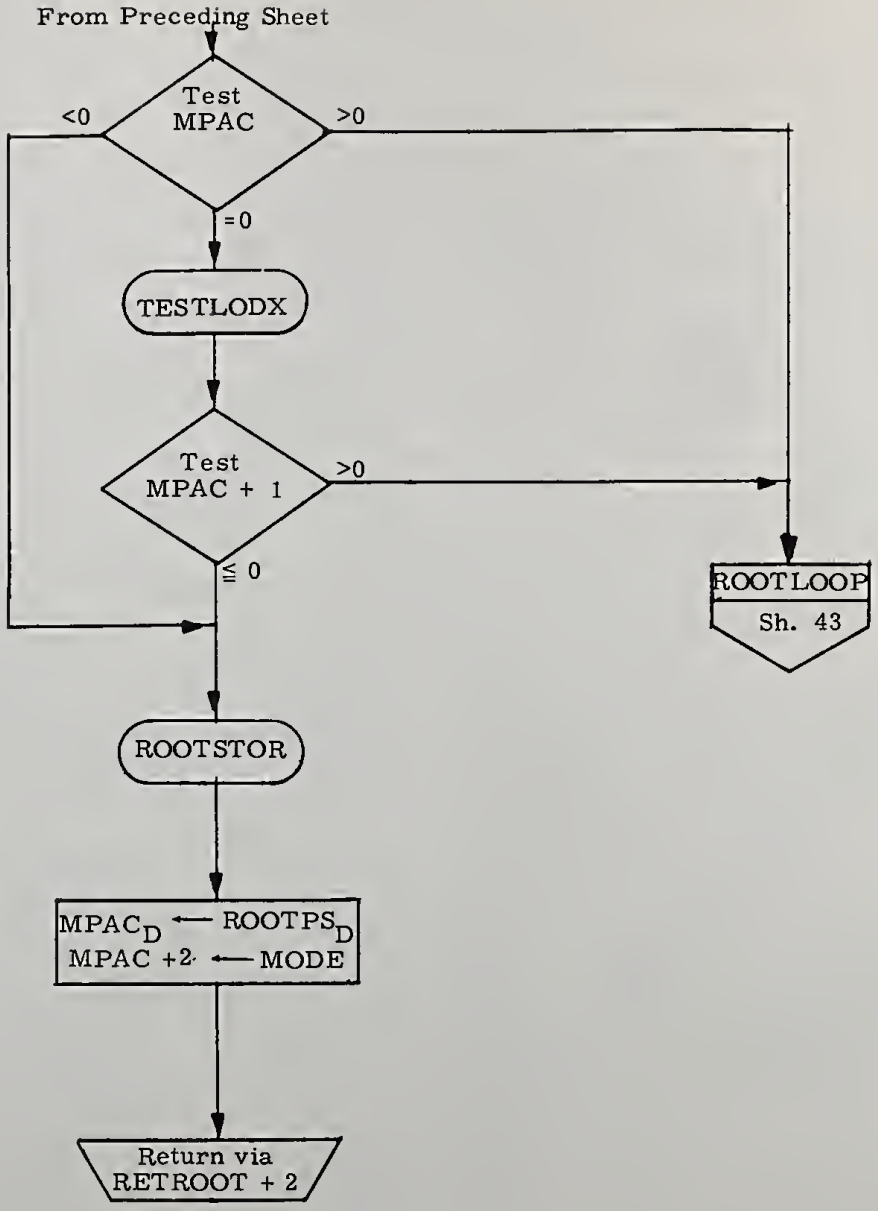
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		Lunar Landing	
PRGMR			
ANALST			DOCUMENT NO.
DOCMR	26/69	LUMINARY-1C	FC-3900
APPR'D	11/25/67	REV	SHEET 41 OF 46



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		Lunar Landing	
PRGMR			
ANALST		LUMINARY 1C	DOCUMENT NO. FC-3900
DOCMR	7/30/69	REV	SHEET 42 OF 46
APPR'D	8/20/69		



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		Lunar Landing	
PRGMR			
ANALST		LUMINARY 1C	DOCUMENT NO. FC-3900
DOCMR	9/24/69	REV	SHEET 43 OF 46
APPR'D	10/26/69		



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		Lunar Landing	
PRGMR		LUMINARY 1C	DOCUMENT NO. FC-3900
ANALST			
DOCMR	9/04/69	REV	SHEET 44 OF 46
APPR'D	10/24/69		

SUBROUTINES CALLED ON
OTHER FLOWCHARTS

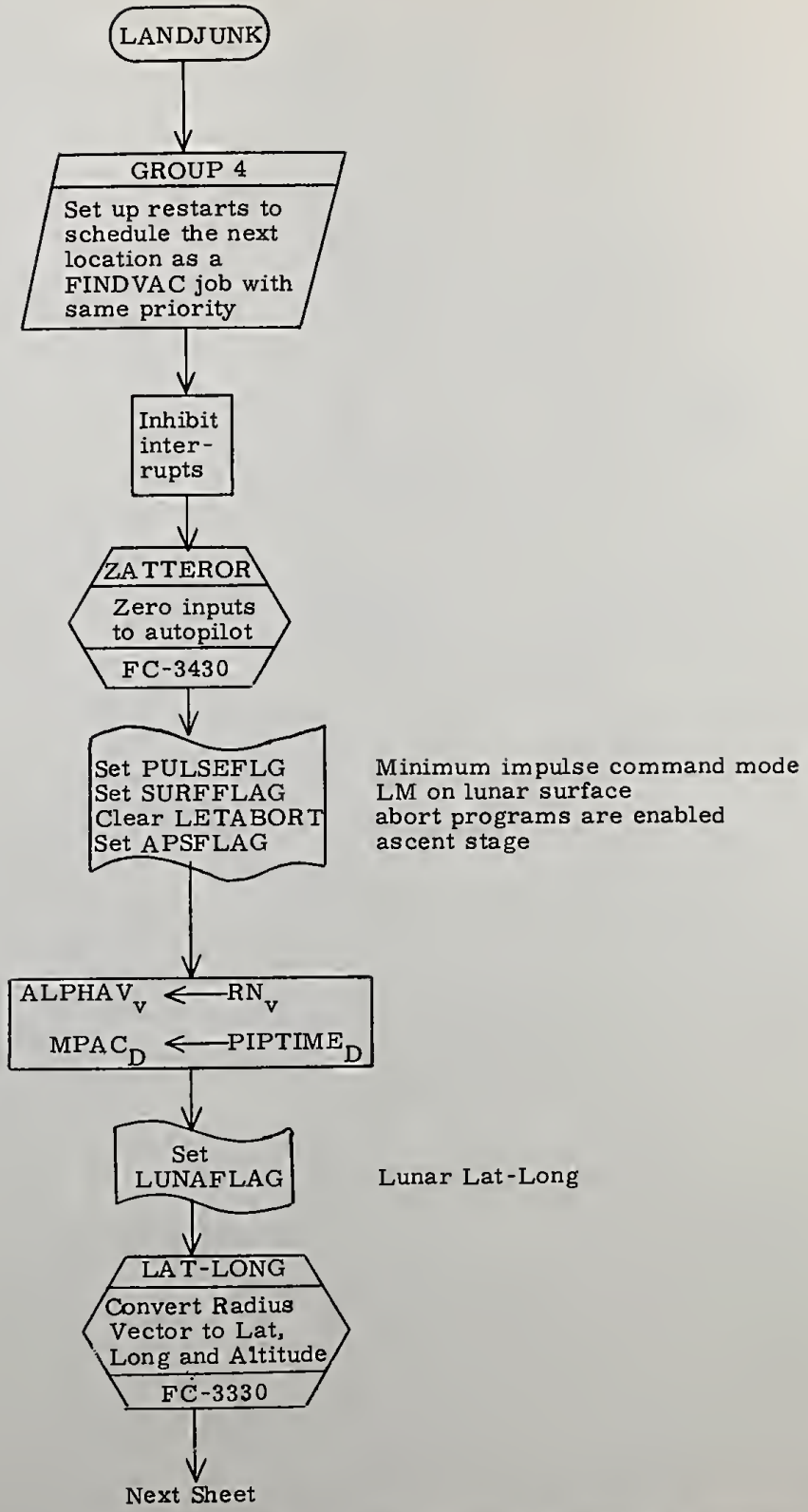
Subroutine	Flowchart	Description	Where Called
RO2BOTH	FC-3220	IMU status check	Sh. 2
RP-TO-R	FC-3340	Transform from planetary to basic reference system	Sh. 3
GUIDINIT	FC-3950	Initialize WM_V and $\|LAND\|_D$	Sh. 3
LEMPREC	FC-3350	Integrate LM state vector	Sh. 3
MUNGRAV	FC-3850	Compute lunar gravitational acceleration	Sh. 4
NEWMODEX	FC-3020	Set new major mode	Sh. 6
C13STALL	FC-3340	Wait till ok to write ch. 13	Sh. 7
PRIOCHNG	FC-3030	Change job priority	Sh. 8
ALARM	FC-3140	Store alarm code; turn on program alarm light	Sh. 12, 19, 26
INTSTALL	FC-3350	Test availability of integration	Sh. 19
INTEGRVS	FC-3350	Integrate state vector	Sh. 20
STCLOK2	FC-3840	Schedule start of CLOCKTASK	Sh. 21
R51P63	FC-3510	IMU realignment	Sh. 22
PFLITEDB	FC-3440	Zero attitude errors, set deadband to 1°	Sh. 22
R6OLEM	FC-3420	Perform auto attitude maneuver	Sh. 23
MAKECADR	FC-3060	Form return address in A	Sh. 24
SETPOS	FC-3935	Compute altitude and velocity beam vectors for position 1	Sh. 24
FINDCDUW	FC-3950	Compute commands to autopilot	Sh. 26
STOPRATE	FC-3430	Zero inputs to autopilot	Sh. 26
ZATTEROR	FC-3430	Zero inputs to autopilot	Sh. 27
CDU*NBSM	FC-3320	Transform vector from NB to SM coordinates	Sh. 31
TPAGREE	FC-3070	Force sign agreement of $MPAC_T$	Sh. 41
POWRSERS	FC-3070	Double precision polynomial evaluator	Sh. 43

Name	Meaning When Set	Meaning When Clear	Where Set	Where Cleared	Where Tested
NOTHROTL Flag 5 Bit 12	Inhibit full throttle	Permit full throttle		Sh. 2	
REDFLAG Flag 6 Bit 6	Landing site redesignation permitted	Landing site redesignation not permitted	Sh. 29	Sh. 2, 7, 28	Sh. 9, 28
LRBYPASS Flag 11 Bit 15	Bypass all LR updates	Do not bypass LR updates		Sh. 2	
MUNFLAG Flag 6 Bit 8	SERVICER calls MUNRVG	SERVICER calls CALCRVG	Sh. 2		
P25 FLAG Flag 0 Bit 9	P25 operating	P25 not operating		Sh. 2	
RNDVZ FLG Flag 0 Bit 7	P20 running	P20 not running		Sh. 2	
XOVINFLG Flag 13 Bit 9	X-axis override locked out	X-axis override okay		Sh. 6	
INTYPFLG Flag 3 Bit 4	Conic integration	Encke integration	Sh. 20		
MOONFLAG Flag 0 Bit 12	Moon is sphere of influence	Earth is sphere of influence	Sh. 20		
STEERSW Flag 2 Bit 11	Sufficient thrust is present	Insufficient thrust is present			Sh. 25
FLUNDISP Flag 8 Bit 10	Current guidance displays inhibited	Current guidance displays permitted			Sh. 26

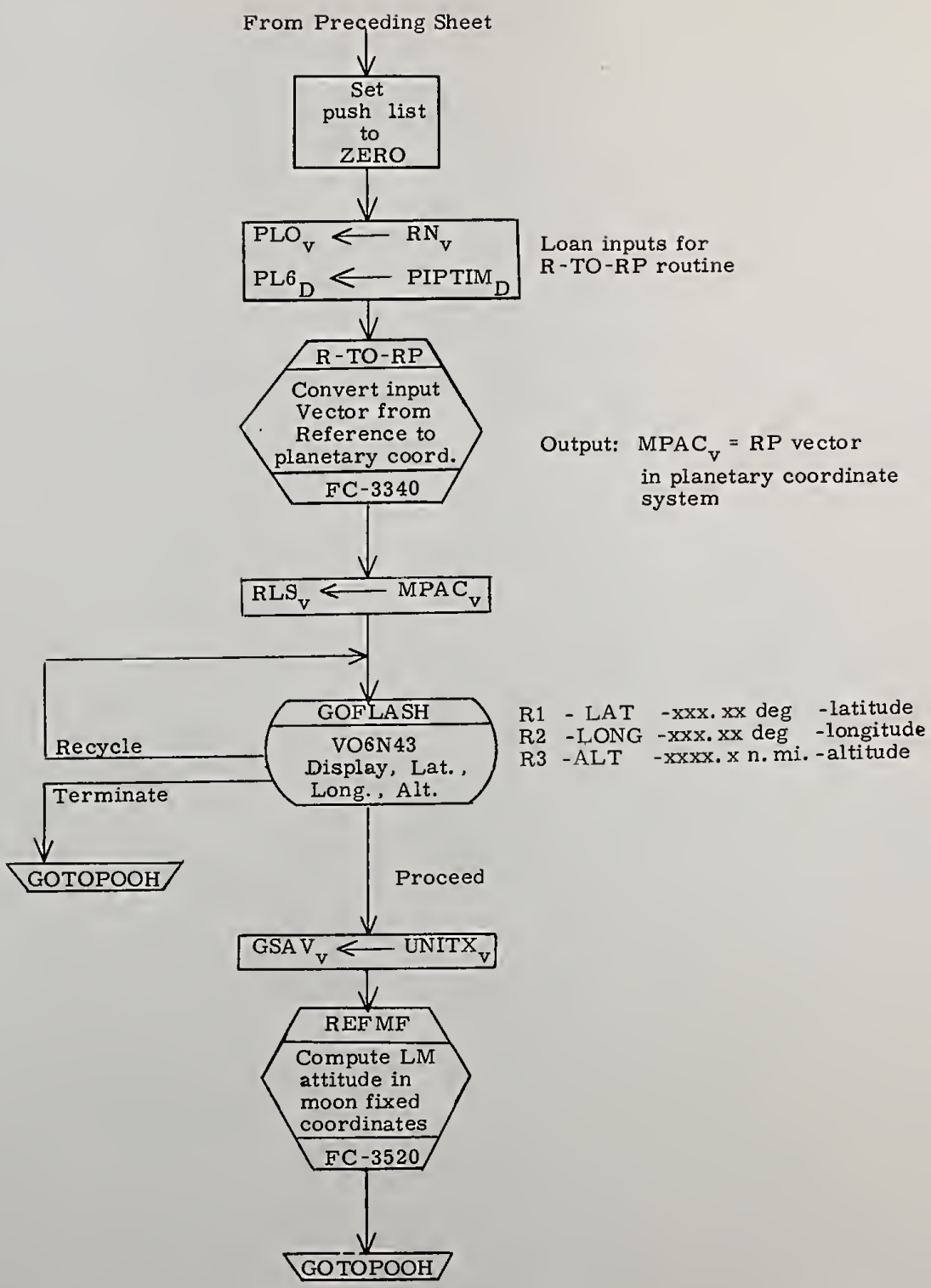
LANDING CONFIRMATION

LANDJUNK Sh. 2

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		Landing Confirmation	
PRGMR	11/26/69		
ANALST		LUMINARY 1C	DOCUMENT NO. FC-3910
DOCMR	11/21/69		
APPR'D	11/26/69	REV	SHEET 1 OF 5



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		Landing Confirmation	
PRGMR	11/24/69		
ANALST		LUMINARY 1C	DOCUMENT NO. FC 3910
DOCMR	11/24/69		
APPR'D	11/26/69	REV	SHEET 2 OF 5



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN Joe Sullivan	10/15/69	Landing Confirmation	
PRGMR Frances Kirwan	11/24/69		
ANALST		LUMINARY 1C	DOCUMENT NO. FC-3910
DOCMR W Daggett	11/21/69		
APPR'D Robert M. Eyles	11/26/69	REV	SHEET 3 OF 5

FLAGS

Name	Meaning When Set	Meaning When Cleared	Where Set	Where Cleared	Where Tested
PULSEFLG FLAG 13 BIT 15	Minimum impulse command mode	Not in minimum impulse command mode	Sh. 2		
SURFFLAG FLAG 8 BIT 8	LM on lunar surface	LM not on lunar surface	Sh. 2		
LETABORT FLAG 9 BIT 9	Abort programs are enabled	Abort programs are not enabled		Sh. 2	
APSFLAG FLAG 10 BIT 13	Ascent stage	Descent stage	Sh. 2		
LUNAFLAG FLAG 3 BIT 12	Lunar lat-long	Earth lat-long	Sh. 2		

MIT INSTRUMENTATION LAB
CAMBRIDGE, MASS.

DRAWN
PRGMR
ANALST
DOCMR
APPR'D

APOLLO GUIDANCE AND NAVIGATION

Landing Confirmation

LUMINARY 1C

DOCUMENT NO.
FC-3910

REV

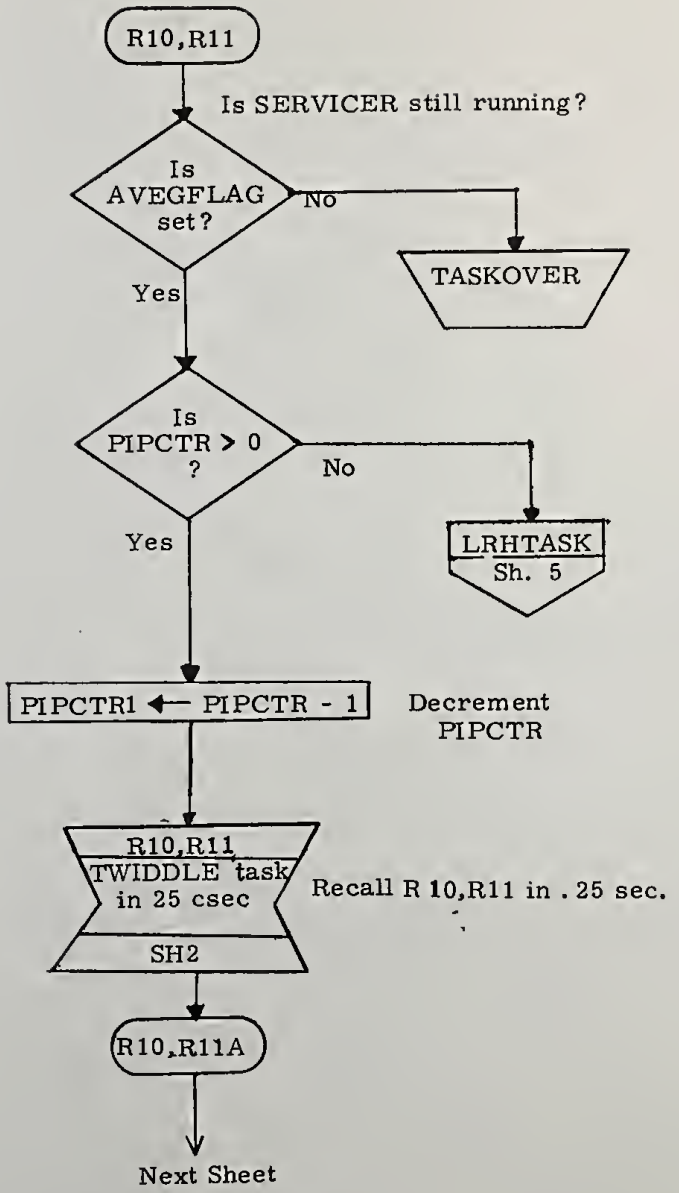
SHEET 4 OF 5

SUBROUTINES CALLED ON OTHER FLOWCHARTS

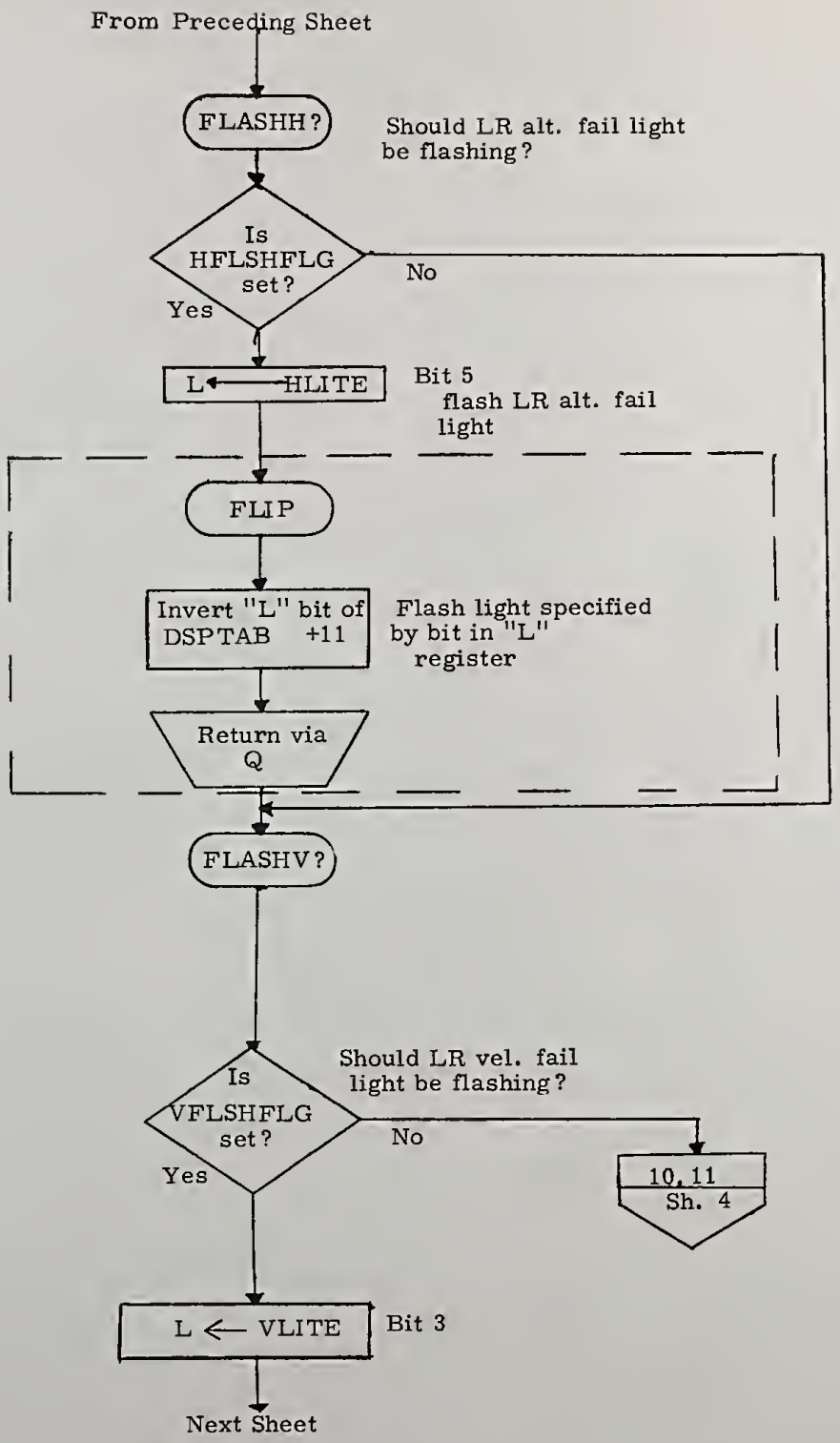
Subroutine	Flowchart	Description	Where Called
ZATTEROR	FC-3430	Zero inputs to autopilot	Sh. 2
LAT-LONG	FC-3330	Convert radius vector to Lat., Long. and altitude	Sh. 2
R-TO-RP	FC-3340	Convert vector from reference to planetary	Sh. 3
REFMF	FC-3520	Compute LM attitude in moon fixed coordinates	Sh. 3

R09, R10, R11

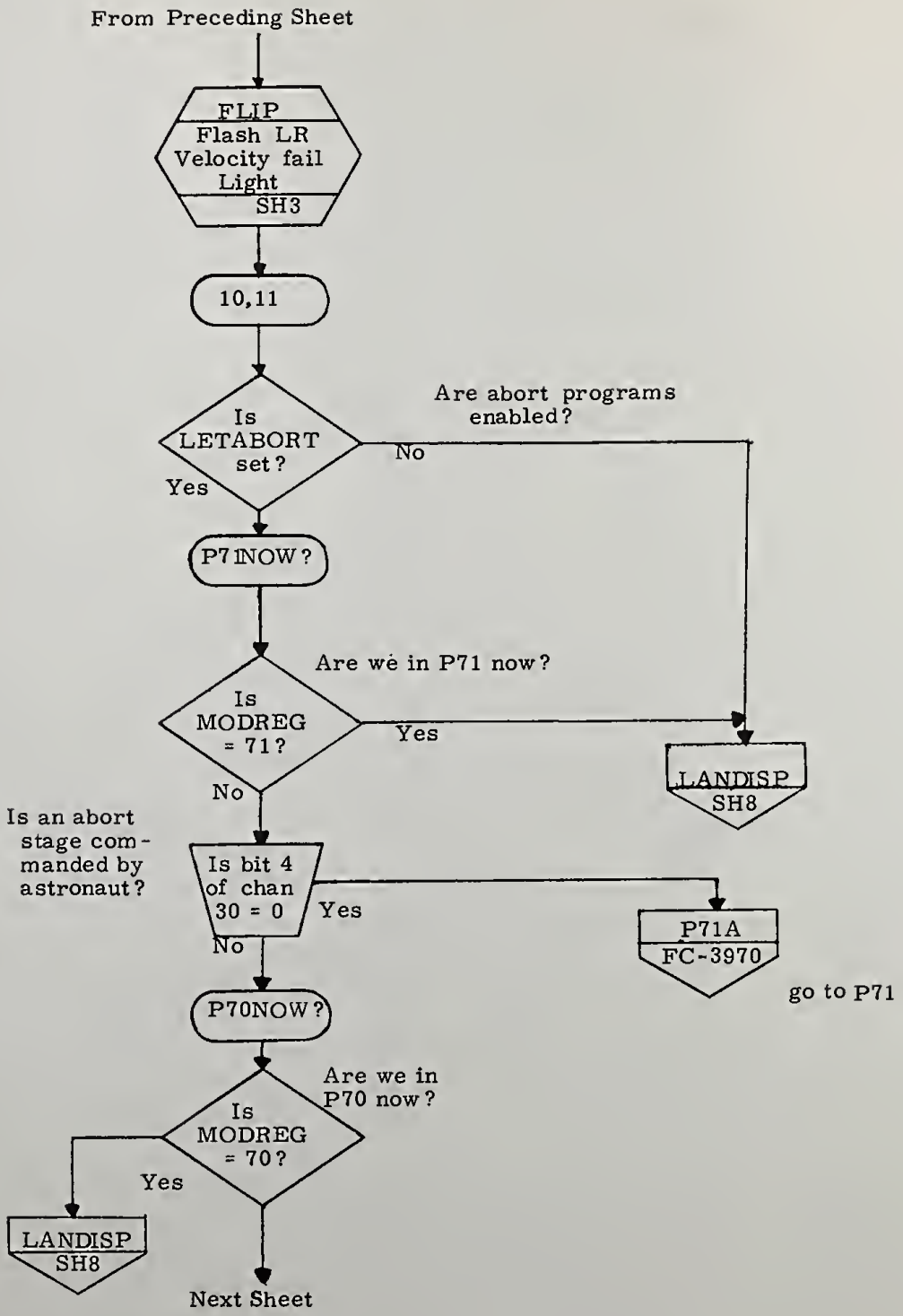
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN D Lutkewitch	10/29/69	R09, R10, R11	
PRGMR A D Bernikowich	11/26/69		
ANALST		LUMINARY 1C	DOCUMENT NO. FC-3930
DOCMR W Dayton	11/21/69		
APPR'D Roberta M. Sutton	11/25/69	REV 1	SHEET 1 OF 24



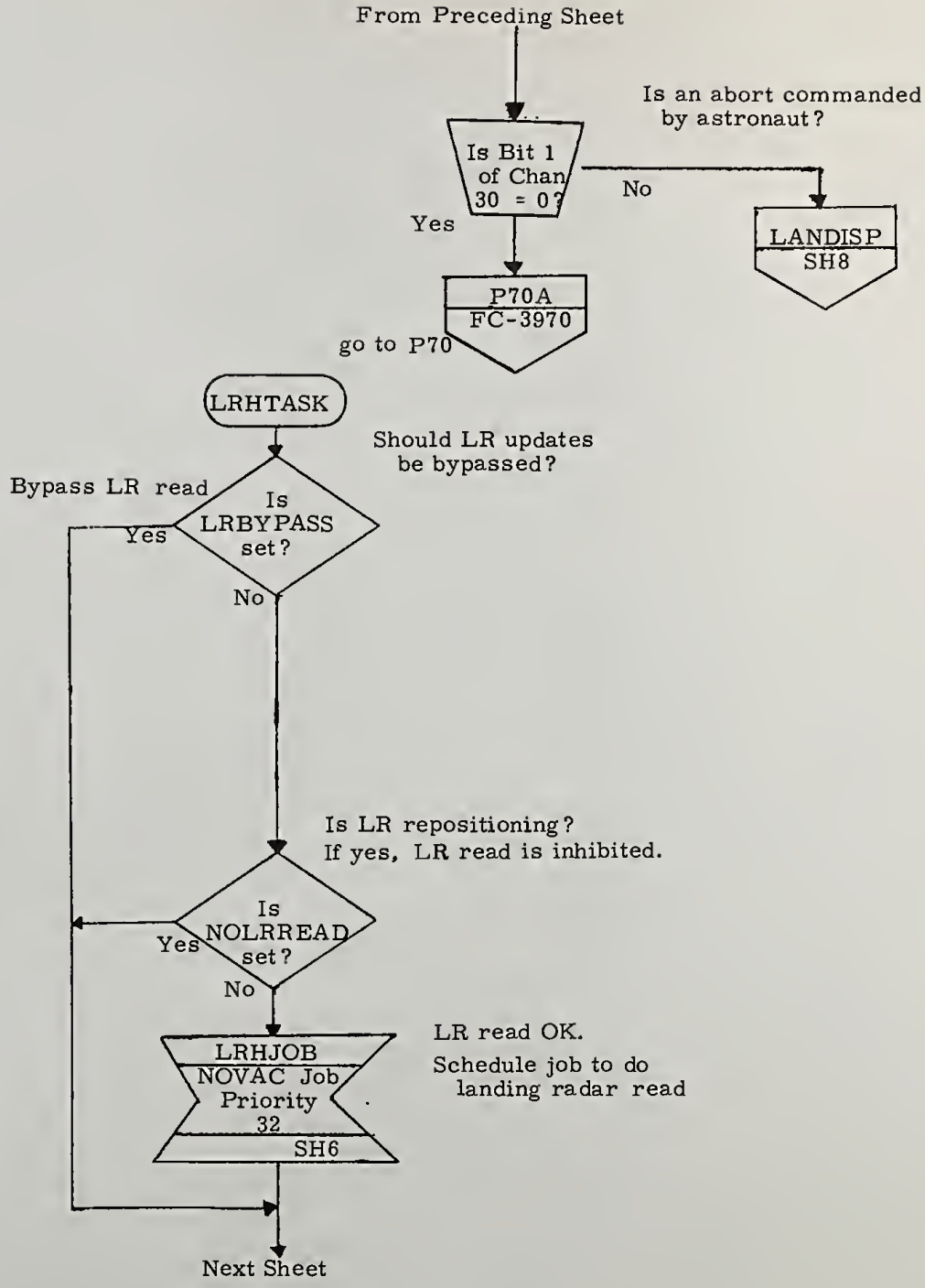
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	10/29/69	R09, R10, R11	
PRGMR	10/29/69	LUMINARY 1C	DOCUMENT NO. FC-3930
ANALST			
DOCMR	9/26/69	REV 1	SHEET 2 OF 24
APPR'D	10/30/69		



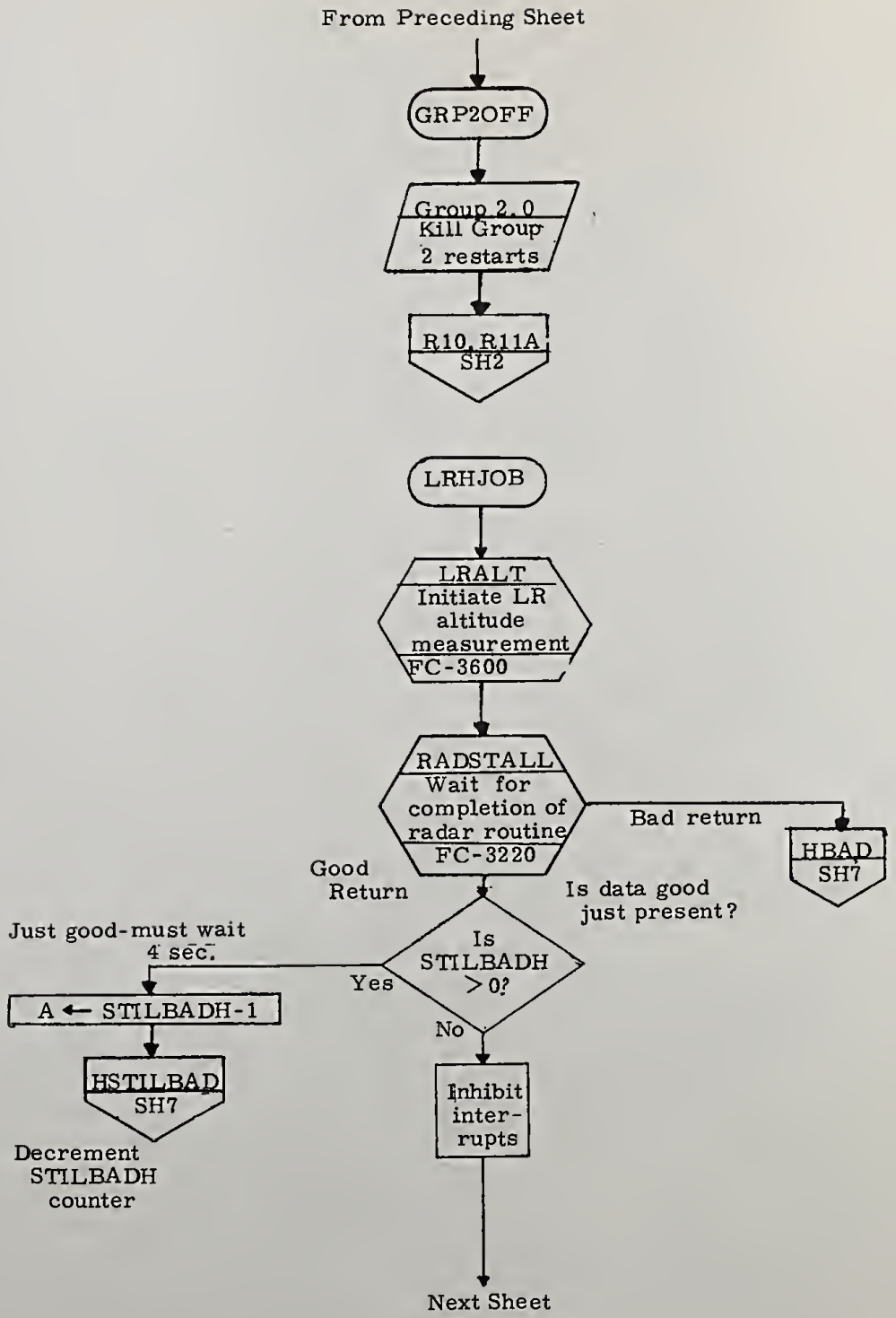
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN D Lukesmith	7/24/69	R09, R10, R11	
PRGMR D Berukoff	10/23/69	LUMINARY 1C	DOCUMENT NO. FC-3930
ANALST			
DOCMR W Danforth	9/26/69		
APPR'D Robert M Swett	10/23/69	REV 1	SHEET 3 OF 24



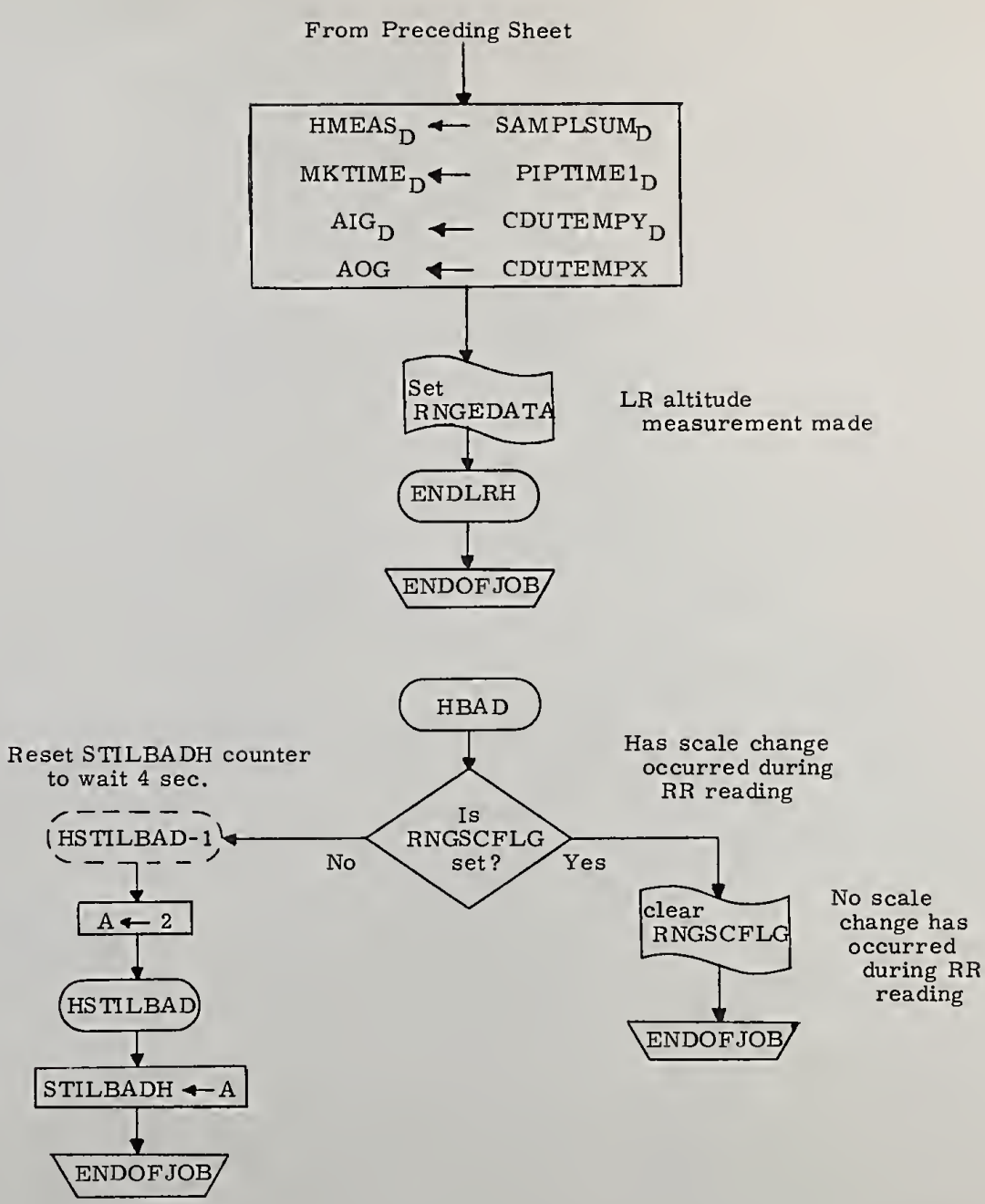
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		R09, R10, R11	
PRGMR	10/29/69		
ANALST		LUMINARY 1C	DOCUMENT NO. FC-3930
DOCMR	7/26/69		
APPR'D	10/29/69	REV 1	SHEET 4 OF 24



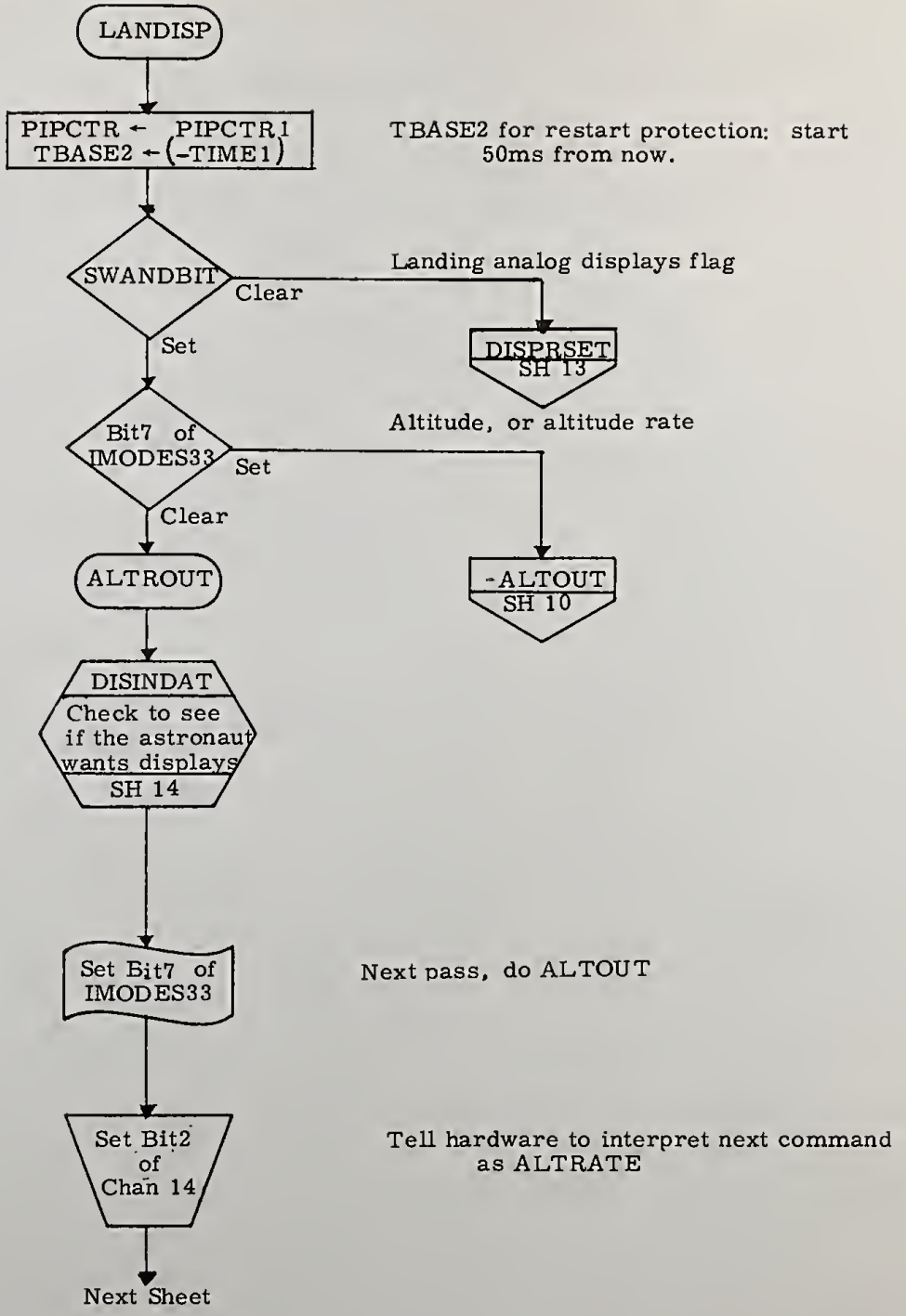
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN D Lutkevich	9/24/69	R09, R10, R11	
PRGMR W Berwick	10/29/69		
ANALST		LUMINARY 1C	DOCUMENT NO. FC-3930
DOCMR W Dyglott	9/26/69		
APPR'D Roberta M Sutton	10/30/69	REV 1	SHEET 5 OF 24



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	9/24/69	R09, R10, R11	
PRGMR	10/29/69		
ANALST		LUMINARY 1C	DOCUMENT NO. Fc-3930
DOCMR	9/26/69		
APPR'D		REV 1	SHEET 6 OF 24

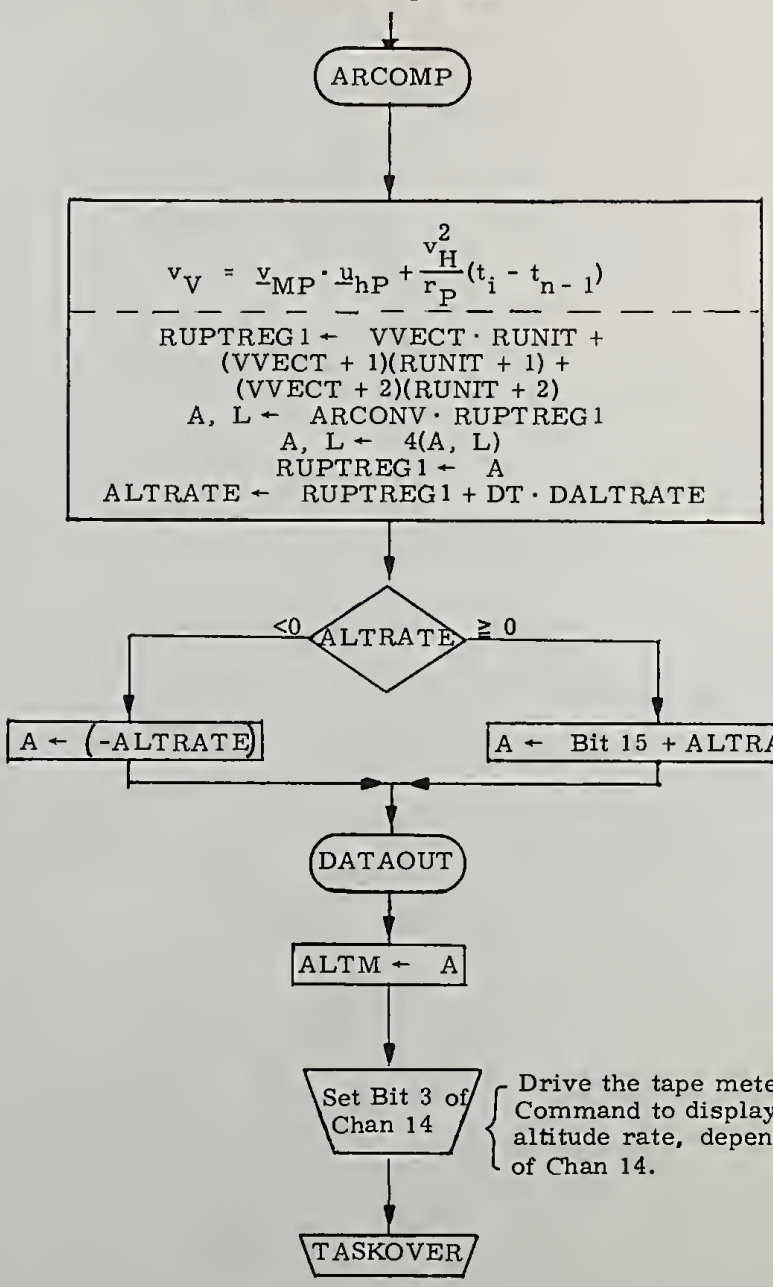


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN D Gutknecht	10/29/69	R09, R10, R11	
PRGMR D Bernhardt	10/29/69	LUMINARY 1C	DOCUMENT NO. FC 3930
ANALST			
DOCMR W C Boyd	9/26/69		
APPR'D R.M. Eyles	10/29/69	REV 1	SHEET 7 OF 24

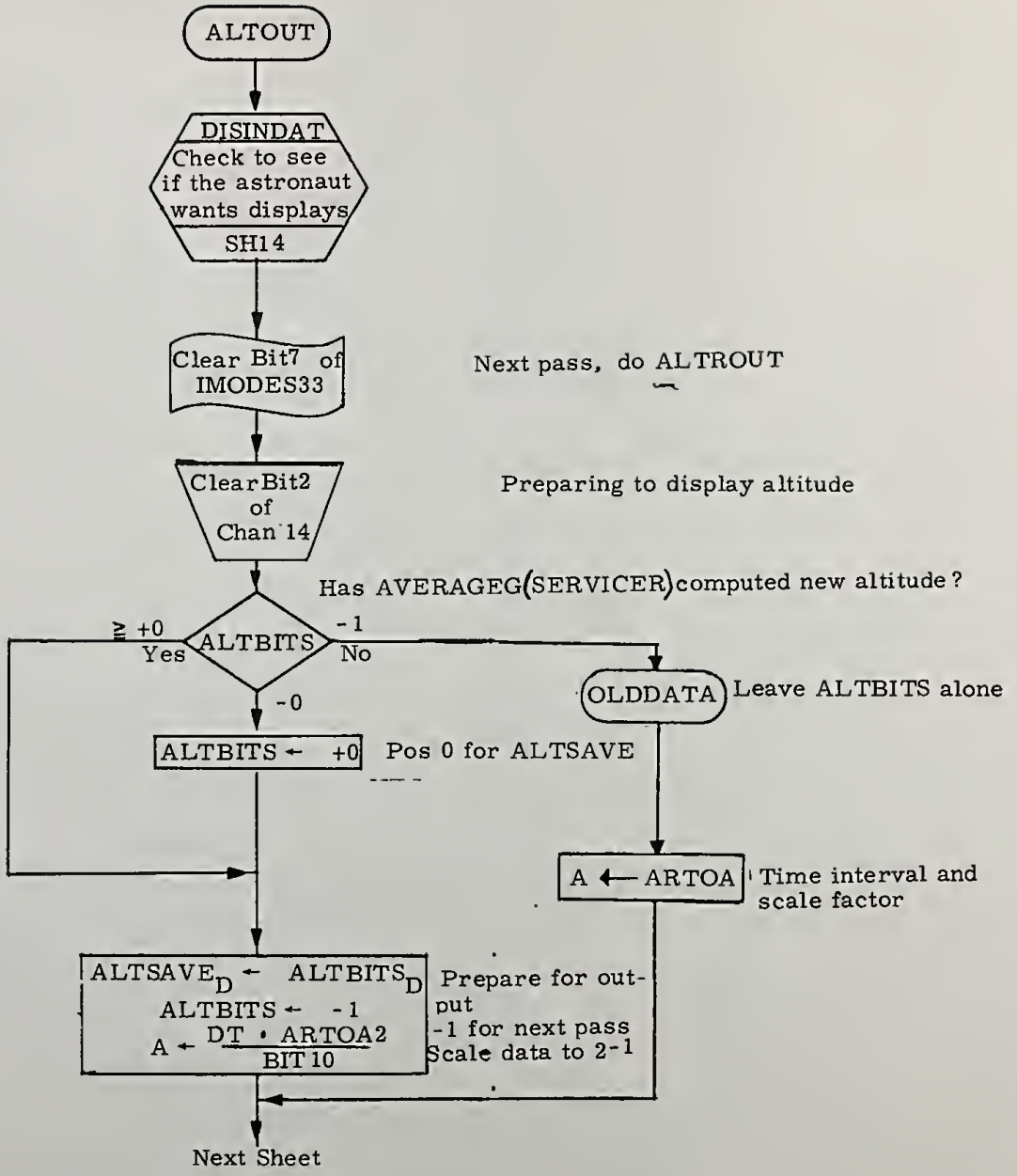


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	9/26/69	R09, R10, R11	
PRGMR	10/23/69		
ANALST		LUMINARY 1C	DOCUMENT NO. FC-3930
DOCMR	9/26/69		
APPR'D	10/24/69	REV 1	SHEET 8 OF 24

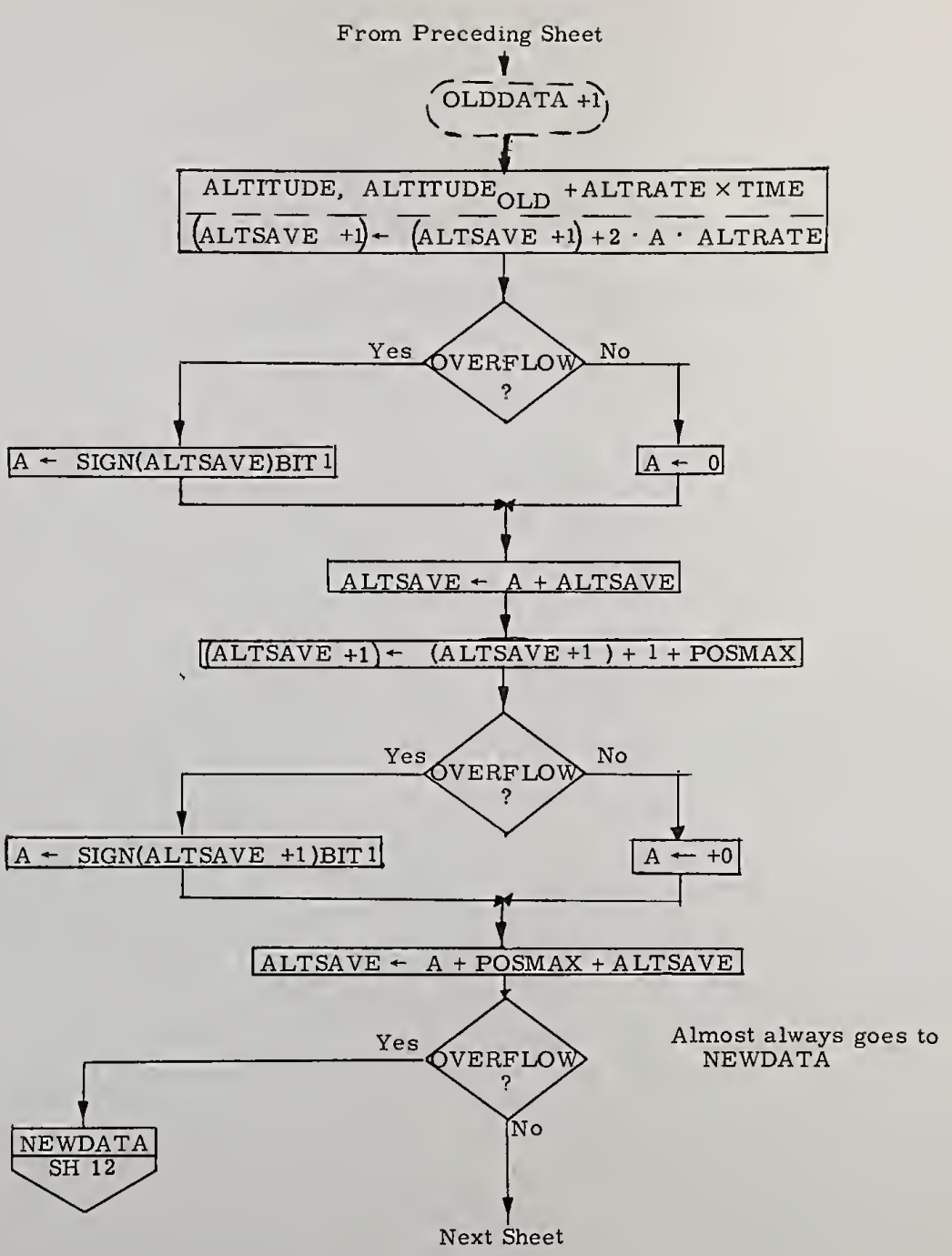
From Preceding Sheet



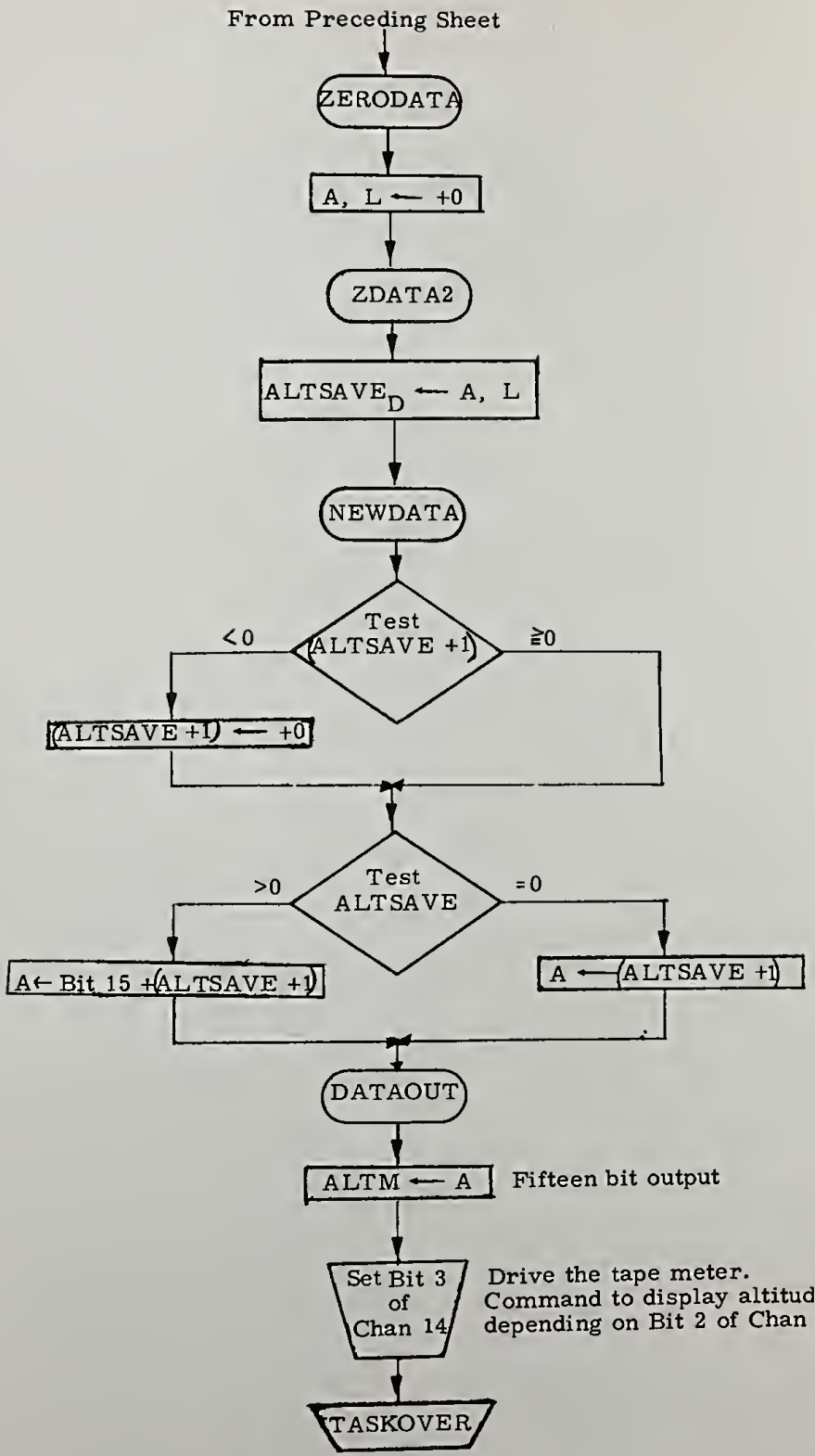
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	9/24/69	R09, R10, R11	
PRGMR	10/29/69	LUMINARY 1C	DOCUMENT NO. FC-3930
ANALST			
DOCMR	9/24/69	REV 1	SHEET 9 OF 24
APPR'D	10/29/69		



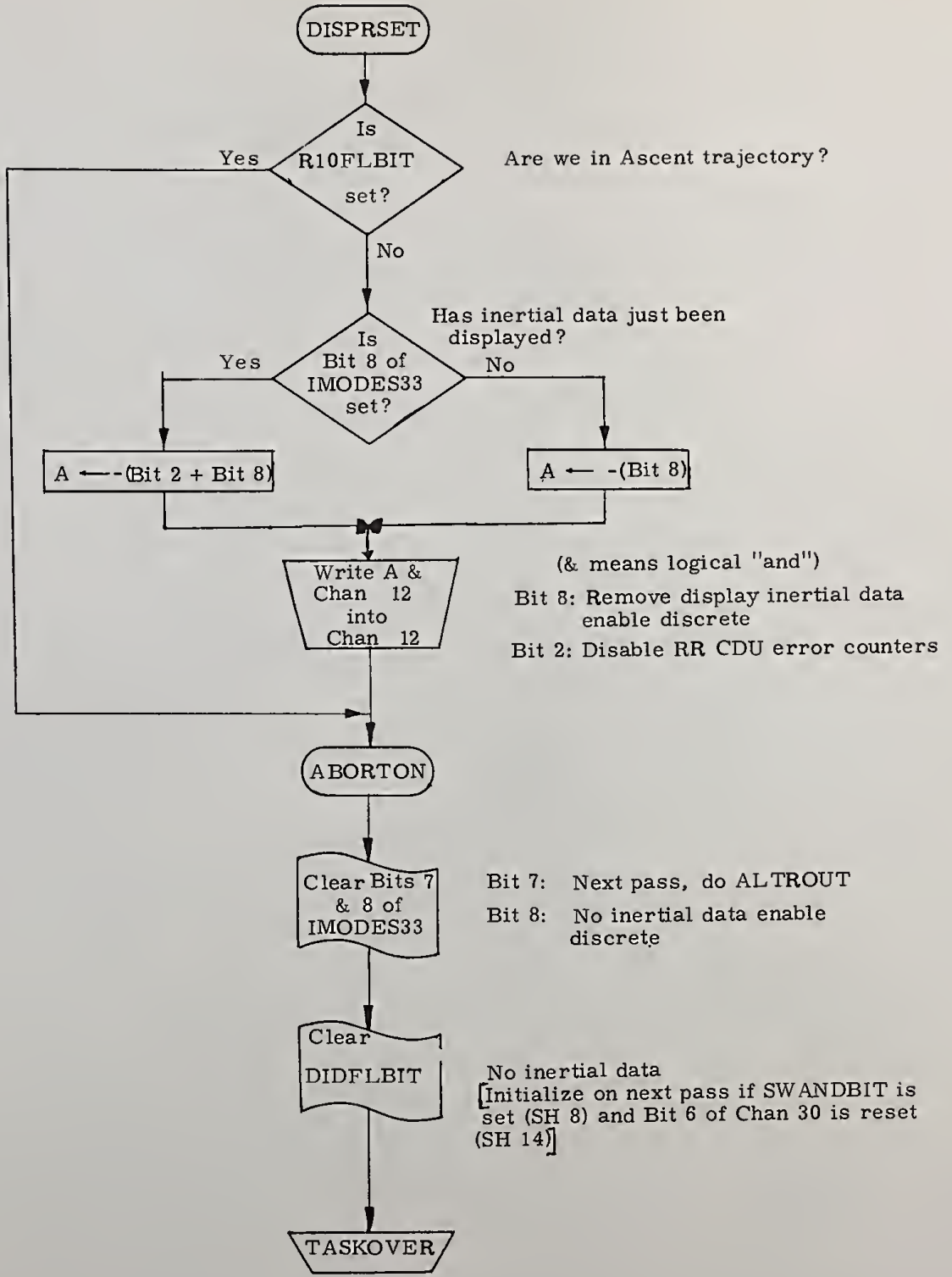
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	12/9/69	R09, R10, R11	
PRGMR	12/23/69		
ANALST		LUMINARY 1C	DOCUMENT NO. FC-3930
DOCMR	12/26/69		
APPR'D	12/29/69	REV 1	SHEET 10 OF 24



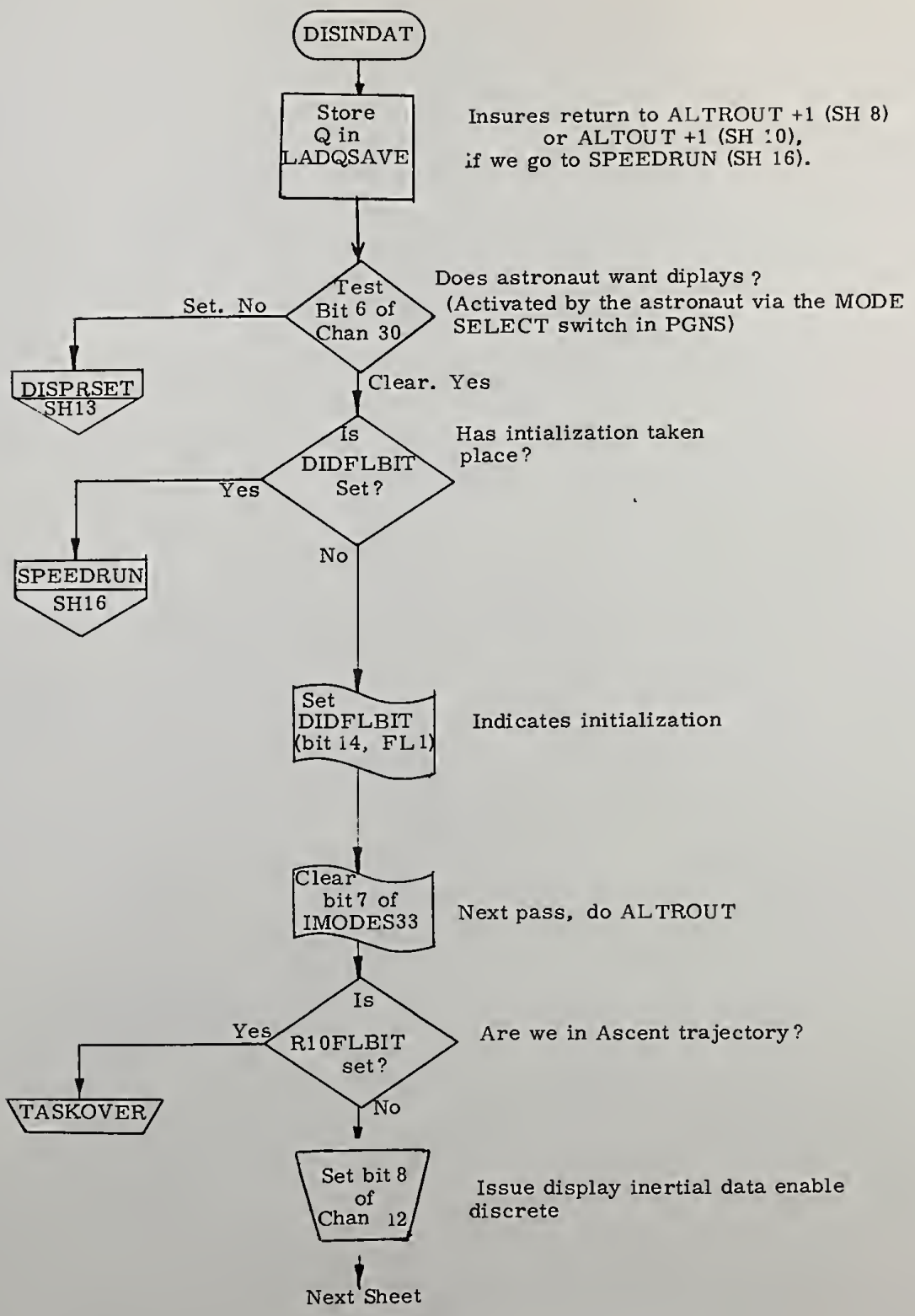
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN D. Lickly Revised	9/24/69	R09, R10, R11	
PRGMR D. Bernhardt	10/29/69		
ANALST		LUMINARY 1C	DOCUMENT NO. FC-3930
DOCMR W Dayhuff	9/24/69		
APPR'D R.M. Eaton	10/30/69	REV 1	SHEET 11 OF 24



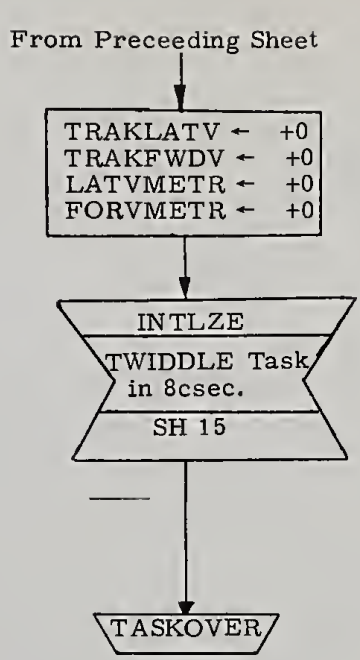
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		R09, R10, R11	
PRGMR	10/29/69		
ANALST		LUMINARY 1C	DOCUMENT NO. PC-3930
DOCMR	9/26/69		
APPR'D	10/30/69	REV 1	SHEET 12 OF 24

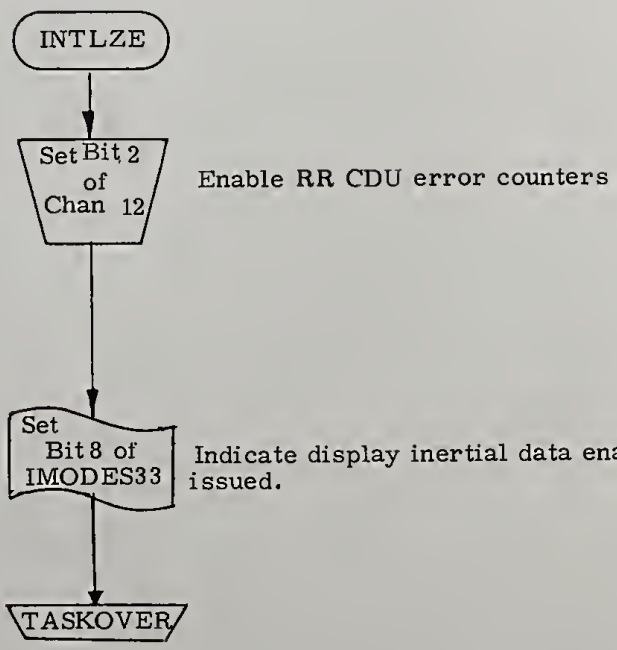


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	9/26/69	R09, R10, R11	
PRGMR	10/29/69		DOCUMENT NO.
ANALST		LUMINARY 1C	FC-3930
DOCMR	9/26/69	REV 1	SHEET 13 OF 24
APPR'D	10/30/69		

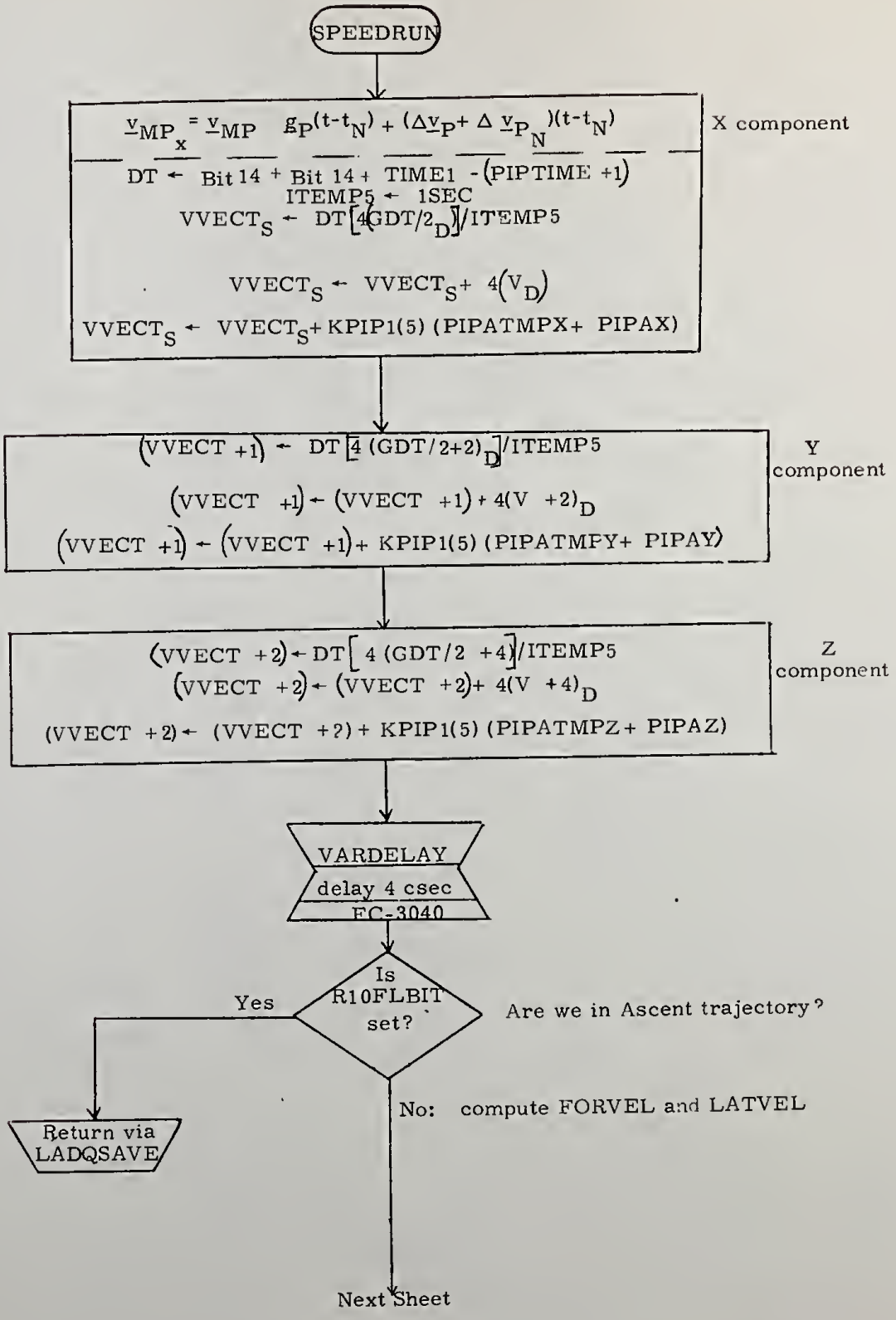


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN D Lickenbrock	9/24/69	R09, R10, R11	
PRGMR D Bernhardt	10/24/69		
ANALST		LUMINARY 1C	DOCUMENT NO. FC-3930
DOCMR M Dapkus	9/26/69		
APPR'D R.M. Eyles	10/24/69	REV 1	SHEET 14 OF 24

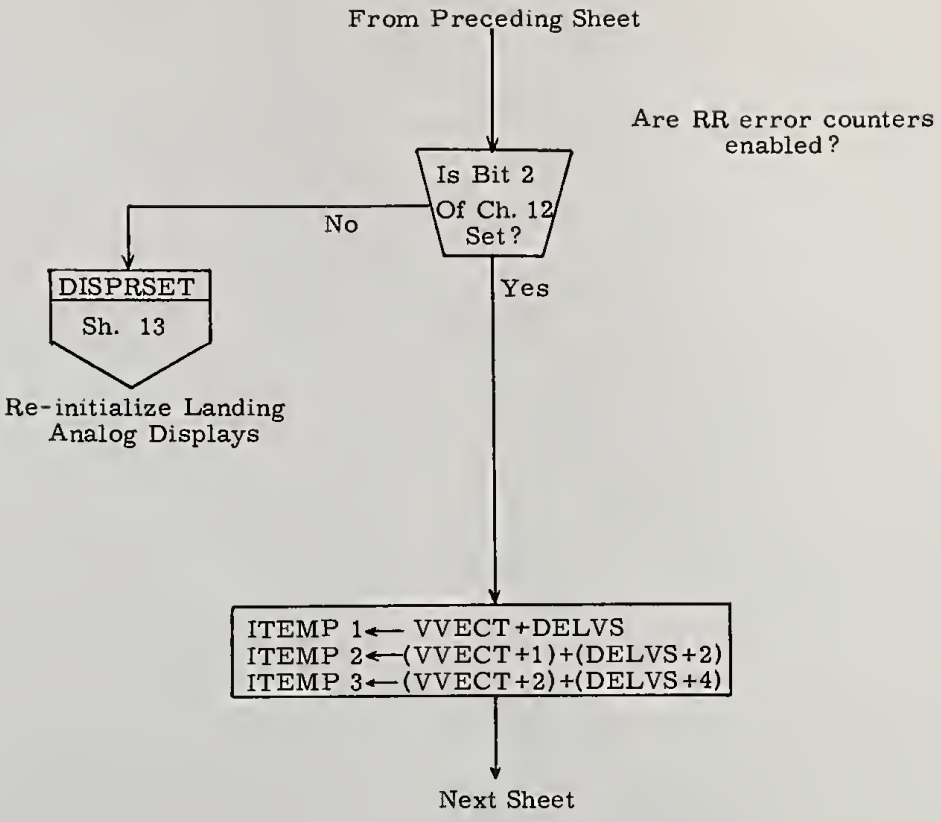




MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	11/26/68	R09, R10, R11	
PRGMR	10/29/69	LUMINARY 1C	DOCUMENT NO. FC-3930
ANALST			
DOCMR	9/26/69	REV 1	SHEET 15 OF 24
APPR'D	10/29/69		



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN D Fulkerson	9/26/69	R09, R10, R11	
PRGMR [illegible]	10/14-24/69		
ANALST		LUMINARY 1C	DOCUMENT NO. FC-3930
DOCMR W Baglivo	9/26/69		
APPR'D R. M. Eyles	10/30/69	REV 1	SHEET 16 OF 24



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN D. Lotkenick	9/24/69	R09, R10, R11	
PRGMR L. Bernhardt	11/25/69		
ANALST		LUMINARY 1C	DOCUMENT NO. FC-3930
DOCMR W. Daybrith	11/21/69		
APPR'D Roberta M. Sutton	11/25/69	REV 1	SHEET 17 OF 24

From Preceding Sheet

$v_{HY} = \pm v_{MP} \cdot u_{HYP}$

RUPTREG1 ← UHYP (ITEMP1)
RUPTREG1 ← RUPTREG1 + ITEMP2 (UHYP +2)
RUPTREG1 ← RUPTREG1 + ITEMP3 (UHYP +4)
VHY ← 2(RUPTREG1)

Velocity directed along the Y-coordinate

$v_{HZ} = \pm v_{MP} u_{HZP}$

RUPTREG1 ← UHZP(ITEMP1)
RUPTREG1 ← RUPTREG1 + (UHZP +2)ITEMP2
RUPTREG1 ← RUPTREG1 + (UHZP +4)ITEMP3
VHZ ← 2(RUPTREG1)

Velocity directed along the Z-coordinate

GET22/32

EBANK ← EBANK6
ITEMP3 ← M22
ITEMP4 ← M32
EBANK ← EBANK7

sin(AOG)
cos(AOG)
} computed by T4RUPT every 0.25 sec

LATFWDV

$v_{HL} = v_{HZ} \sin AOG + v_{HY} \cos AOG$

RUPTREG1 ← ITEMP4(VHY)
RUPTREG1 ← RUPTREG1 + ITEMP3(VHZ)
LATVEL ← 2(RUPTREG1) VELCONV

$v_{HF} = v_{HZ} \cos AOG - v_{HY} \sin AOG$

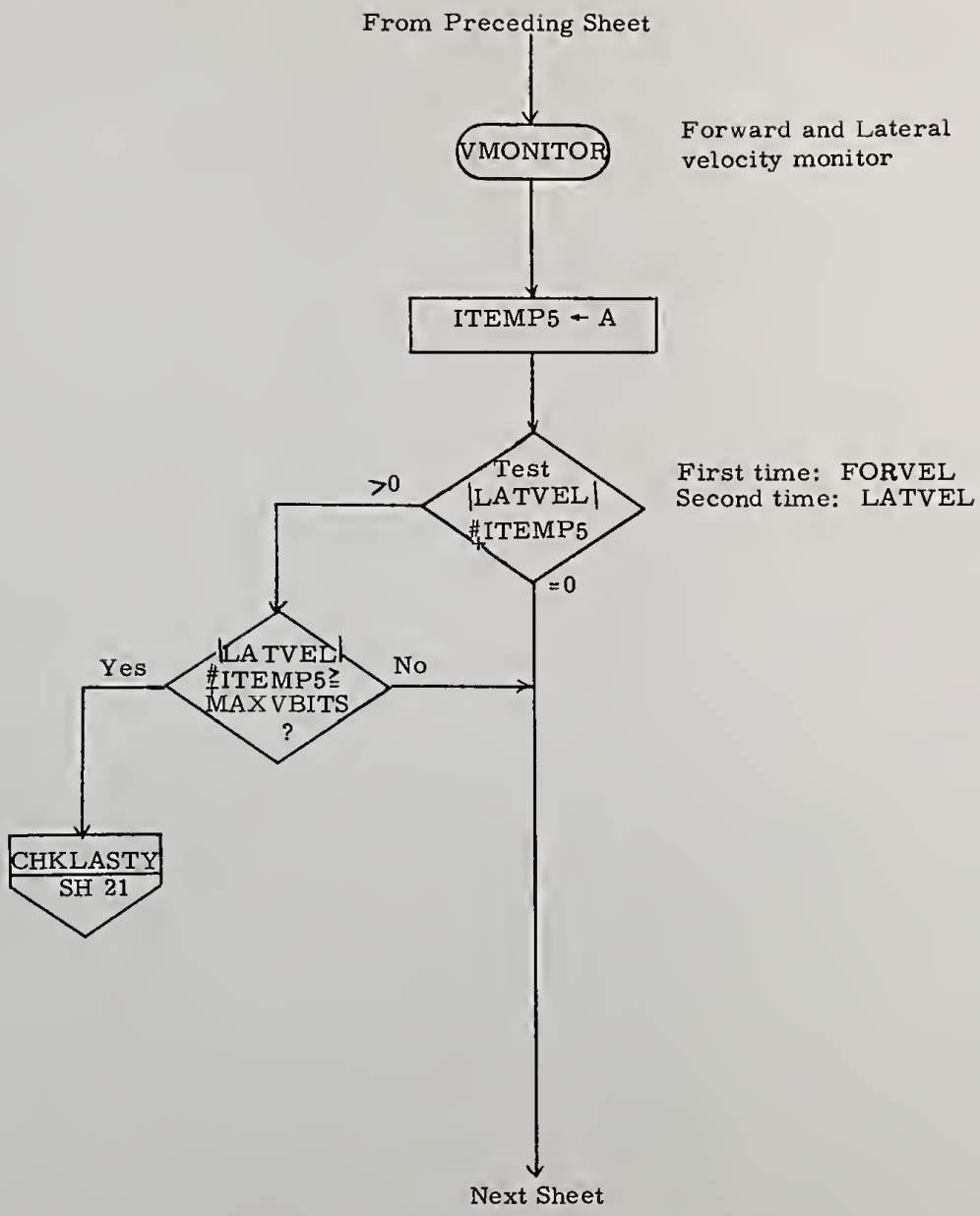
RUPTREG1 ← ITEMP4(VHZ)
RUPTREG1 ← RUPTREG1 - (VHY)ITEMP3
FORVEL ← 2(RUPTREG1) VELCONV

ITEMP6 ← (-MAXVBITS)
A ← ONE

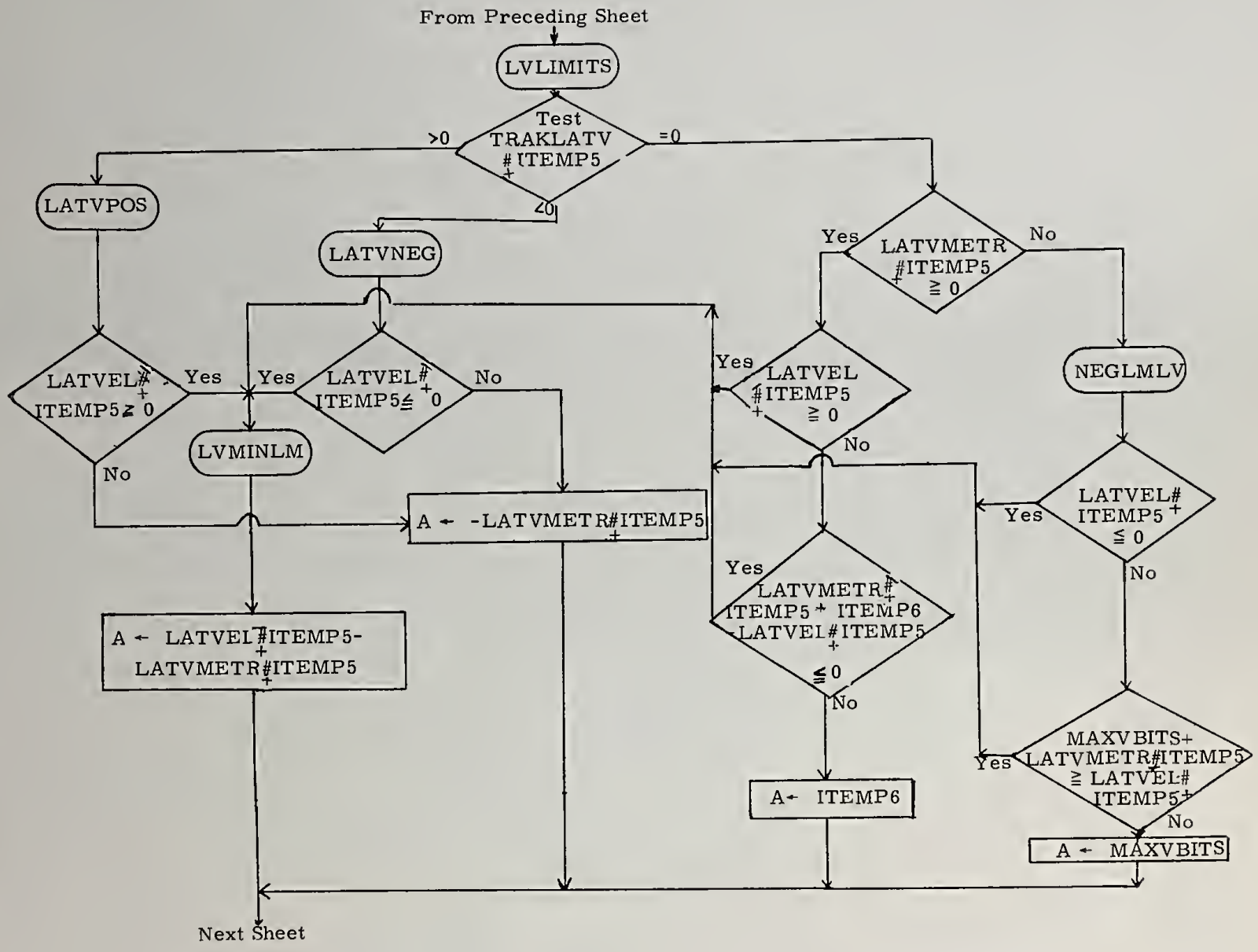
-200 ft/sec
For loop control: 2 times through

Next Sheet

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN D Lutkeuse	7/24/68	R09, R10, R11	
PRGMR R Bennington	10/29/69		DOCUMENT NO.
ANALST		LUMINARY 1C	FC-3930
DOCMR W Dayton	7/26/69	REV 1	SHEET 18 OF 24
APPR'D R M Eyles	10/30/69		



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN E Zuttermeister	9/26/69	R09, R10, R11	
PRGMR D Benitowicz	10/29/69	LUMINARY 1C	DOCUMENT NO. FC 3930
ANALST			
DOCMR W Dayton	9/26/69		
APPR'D R.M. Eutes	10/29/69	REV 1	SHEET 19 OF 24



MIT INSTRUMENTATION LAB
CAMBRIDGE, MASS.

APOLLO GUIDANCE AND NAVIGATION

DRAWN
PRGMR
ANALST
DOCMR
APPR'D R.M. Eyles

9/26/67
10/31/67
9/26/67
12/28/67

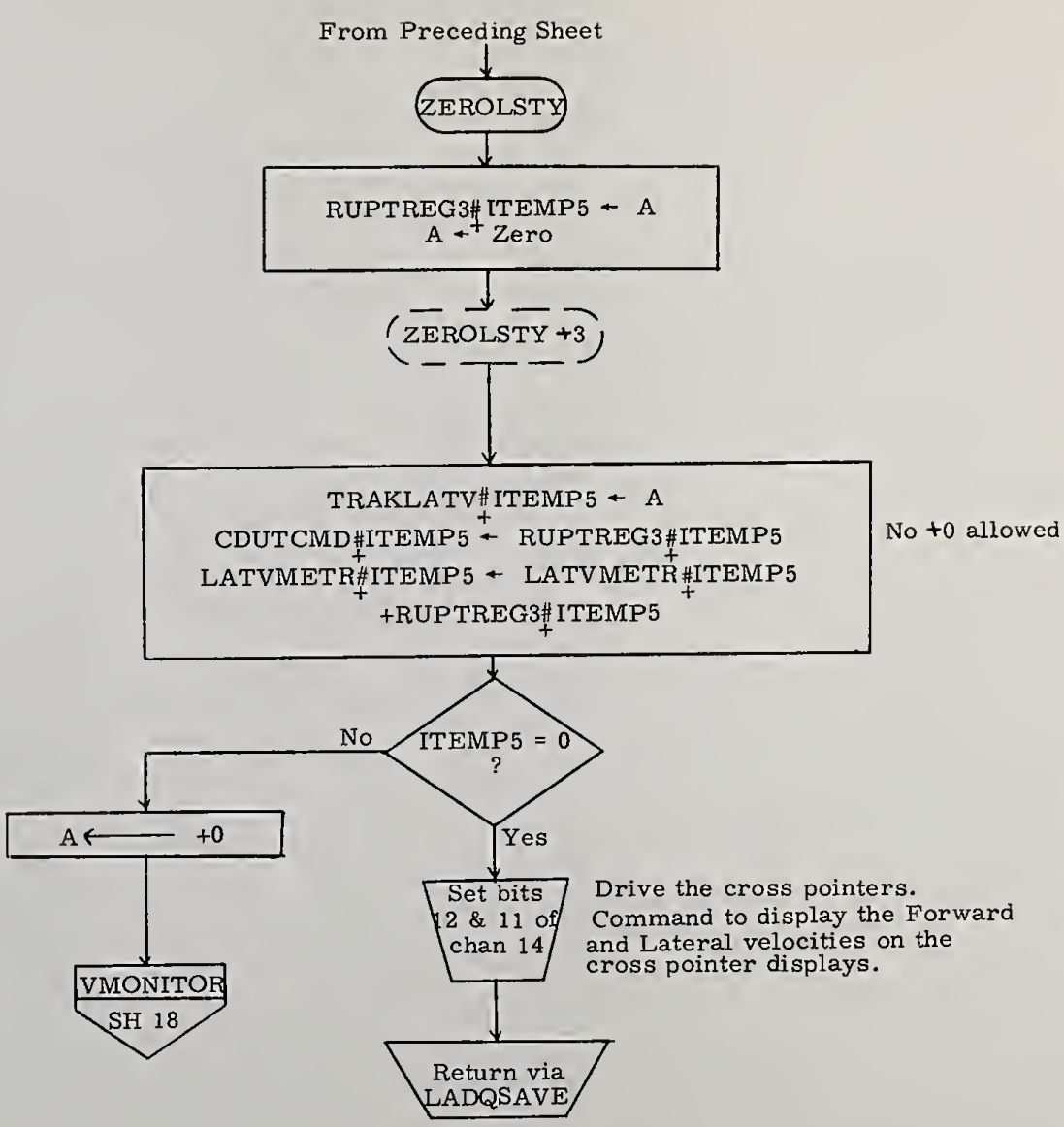
LUMINARY 1C

R09, R10, R11

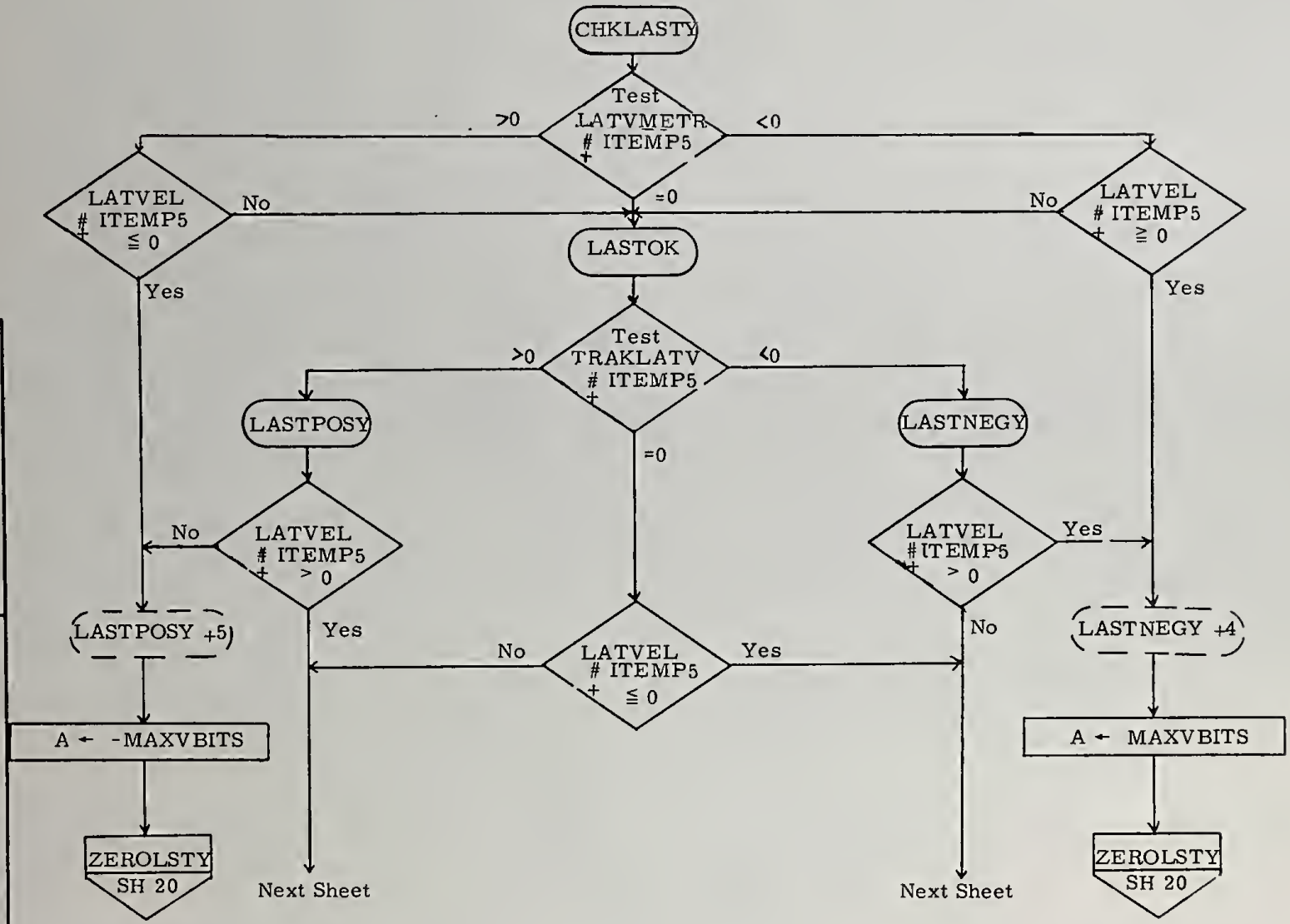
DOCUMENT NO.
FC 3930

REV 1

SHEET 20 of 24



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN D Lutkewitte	11/26/69	R09, R10, R11	
PRGMR R Berningsen	11/24/69		
ANALST			DOCUMENT NO.
DOCMR M Dayton	11/26/69	LUMINARY 1C	FC-3930
APPR'D P M Eyles	11/26/69	REV 1	SHEET 21 OF 24



MIT INSTRUMENTATION LAB
CAMBRIDGE, MASS.

APOLLO GUIDANCE AND NAVIGATION

DRAWN
PRGMR
ANALST
DOCMR
APPR'D R.M. Eaton

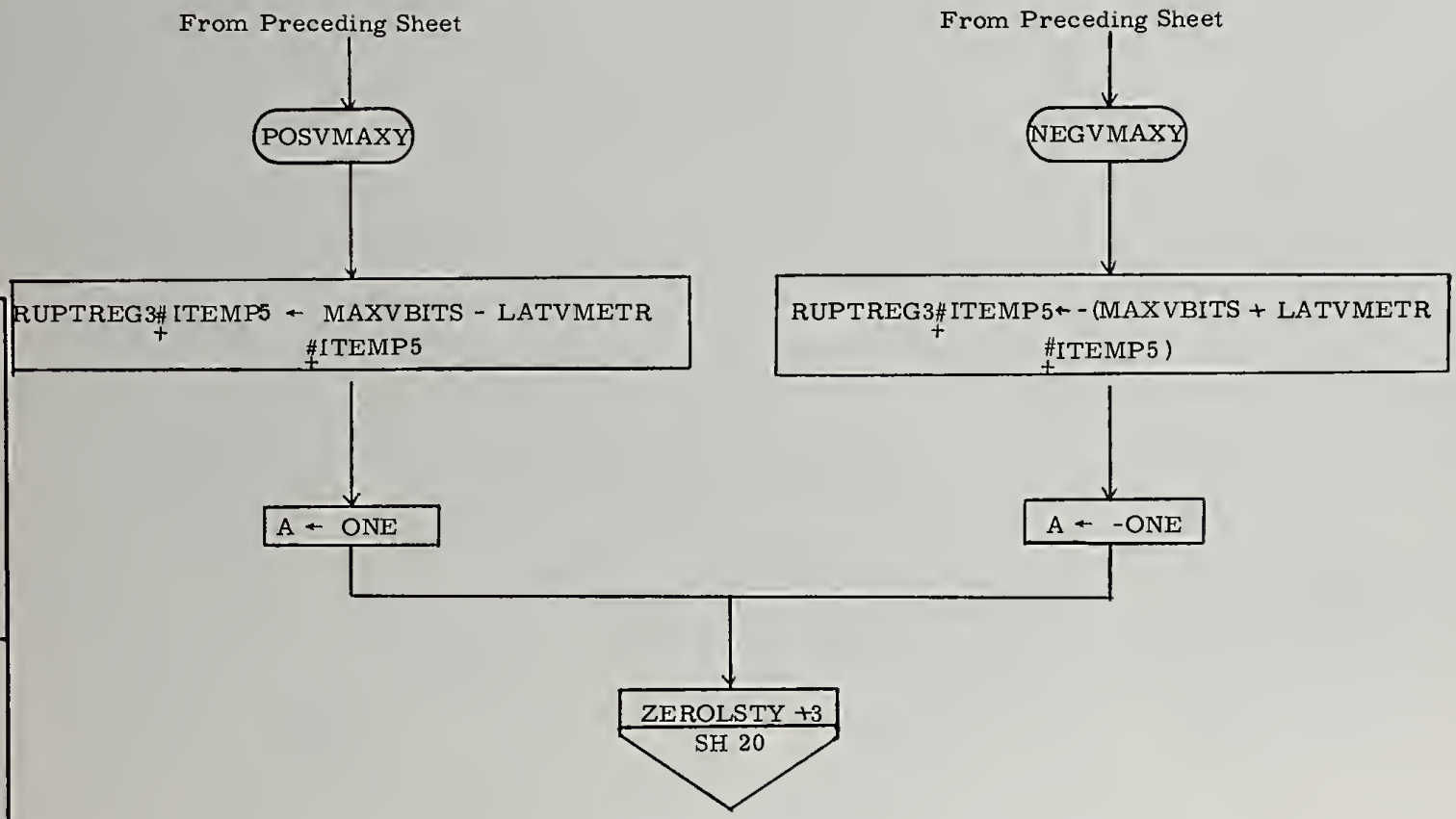
R09, R10, R11

LUMINARY 1C

DOCUMENT NO.
FC-3930

REV 1

SHEET 22 OF 24



MIT INSTRUMENTATION LAB
CAMBRIDGE, MASS.

DRAWN
PRGMR
ANALST
DOCMR
APPR'D

APOLLO GUIDANCE AND NAVIGATION

R09, R10, R11

LUMINARY 1C

DOCUMENT NO.
FC-3930

REV 1

SHEET 23 OF 24

SUBROUTINES CALLED ON OTHER FLOWCHARTS

Subroutine	Flowchart	Description	Where Called
LRALT	FC-3600	Initiate LR altitude measurement	Sh. 6
RADSTALL	FC-3220	Wait for completion of radar routine	Sh. 6

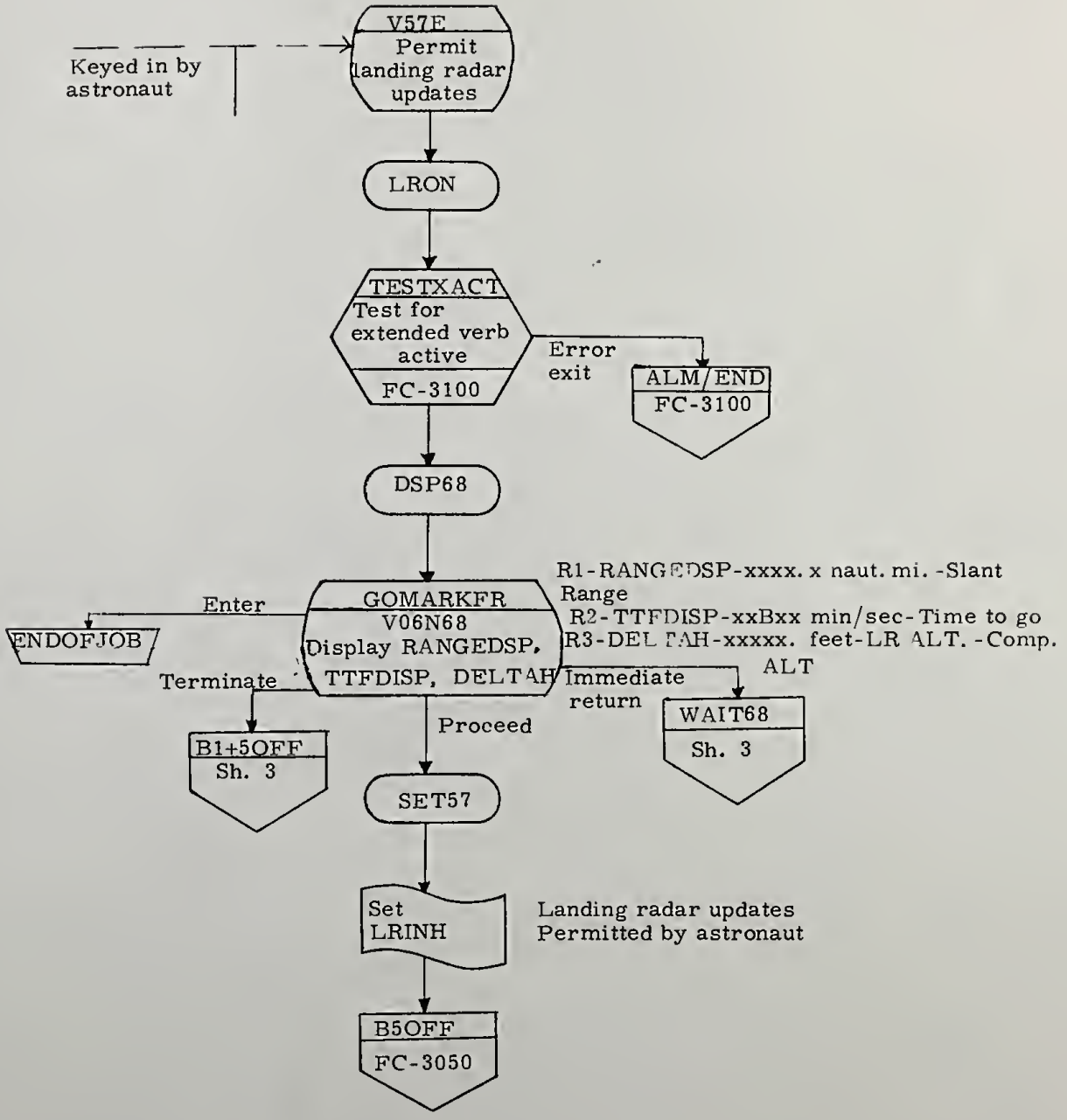
FLAG

Name	Meaning When Set	Meaning When Cleared	Where Set	Where Cleared	Where Tested
AVEGFLAG Flag 7 Bit 5	Average (SERVICER) desired	Average (SERVICER) not desired			Sh. 2
HFLSHFLG Flag 11 Bit 1	LR altitude fail lamp should be flashing	LR altitude fail lamp should not be flashing			Sh. 3
VFLSHFLG Flag 11 Bit 2	LR velocity fail lamp should be flashing	LR velocity fail lamp should not be flashing			Sh. 3
LETABORT Flag 9 Bit 9	Abort programs are enabled	Abort programs are not enabled			Sh. 4
LRBYPASS Flag 11 Bit 15	Bypass all landing radar updates	Do not bypass landing radar updates			Sh. 5
NOLRREAD Flag 11 Bit 10	Landing radar repositioning	Landing radar not repositioning			Sh. 5
RNGEDATA Flag 11 Bit 4	LR altitude measurement made	LR altitude measurement not made	Sh. 7		
RNGSCFLG Flag 5 Bit 10	Scale change has occurred during RR reading	No scale change has occurred during RR reading		Sh. 7	
R10FLAG Flag 0 Bit 2	R10 outputs data to altitude and altitude rate meters only	Besides output when set, also to forward and lateral velocity crosspointer			Sh. 13, 14, 16
D1DFLAG	Inertial data is available	Perform data display initialization functions	Sh. 14	Sh. 13	Sh. 14

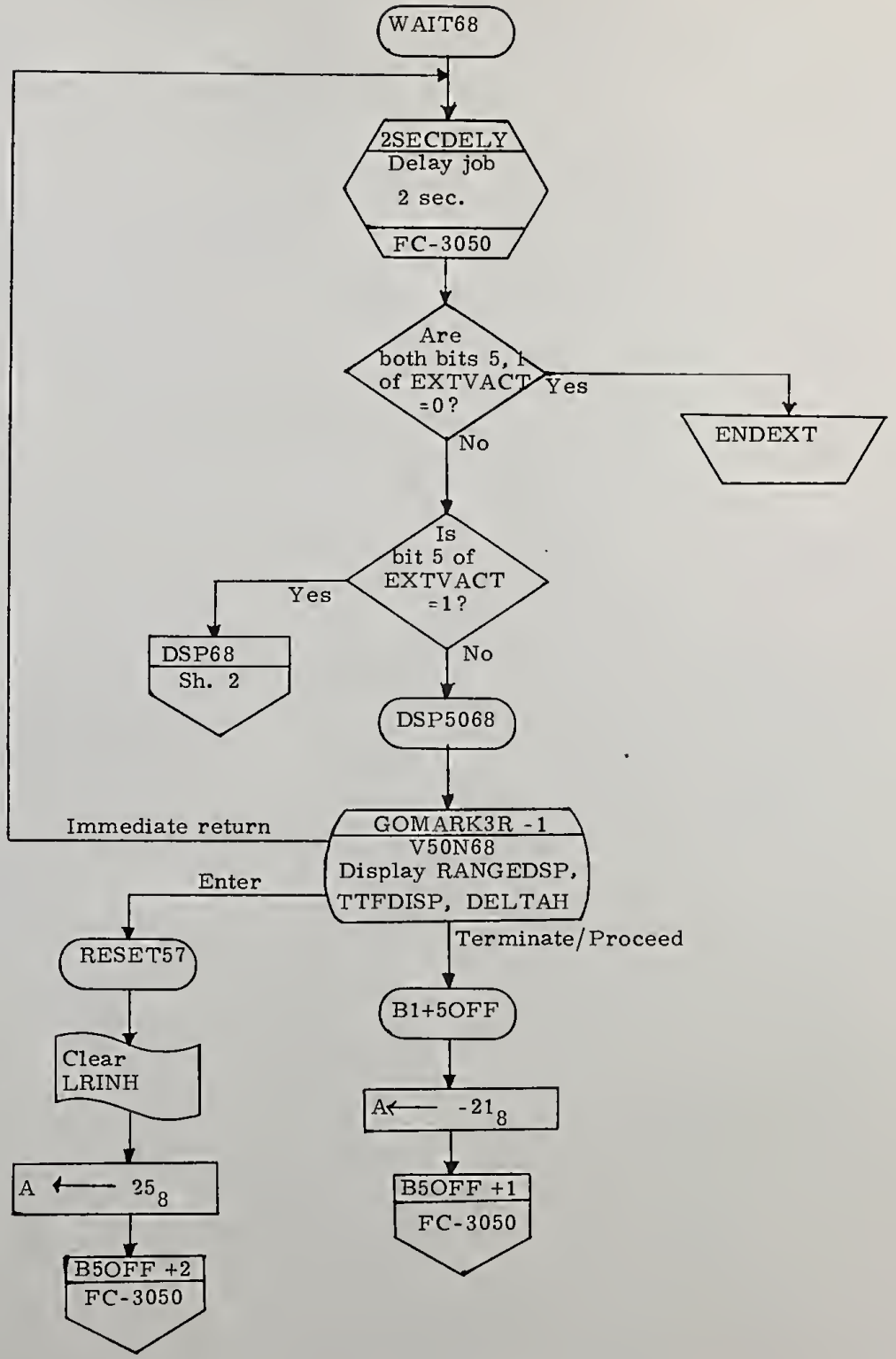
R12 - DESCENT STATE VECTOR UPDATE

MAJOR SUBROUTINES ON THIS CHART

MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN R. Welch	10/23/69	R12 - Descent State Vector Update	
PRGMR D. Moore	12/1/69		
ANALST		LUMINARY 1C	DOCUMENT NO. FC-3935
DOCMR M Dunfield	10/30/69		
APPR'D Roberta M. Sutton	12/1/69	REV 0	SHEET 1 OF 36

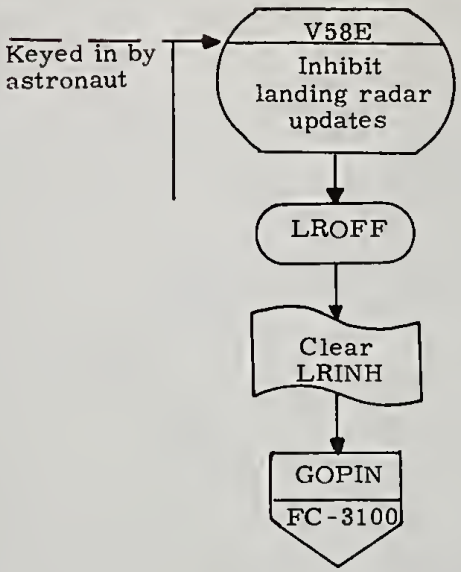


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN G. Welch	12/3/69	R-2 - Descent State Vector Updat	
PRGMR D. Moore	12/1/69		
ANALST		LUM 2 1C	DOCUMENT NO. [illegible]
DOCMR W. Duforth	12/3/69		
APPR'D Roberta M. Eutes	12/4/69	REV 0	SHEET 2 OF 36



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	10/23/69	R12 - Descent State Vector Update	
PRGMR D. Moore	12/1/69		
ANALST		LUMINARY 1C	DOCUMENT NO. E-3935
DOCMR M. Dysart	10/30/69		
APPR'D	12/1/69	REV 0	SHEET 3 OF 36

EXTENDED VERB 58

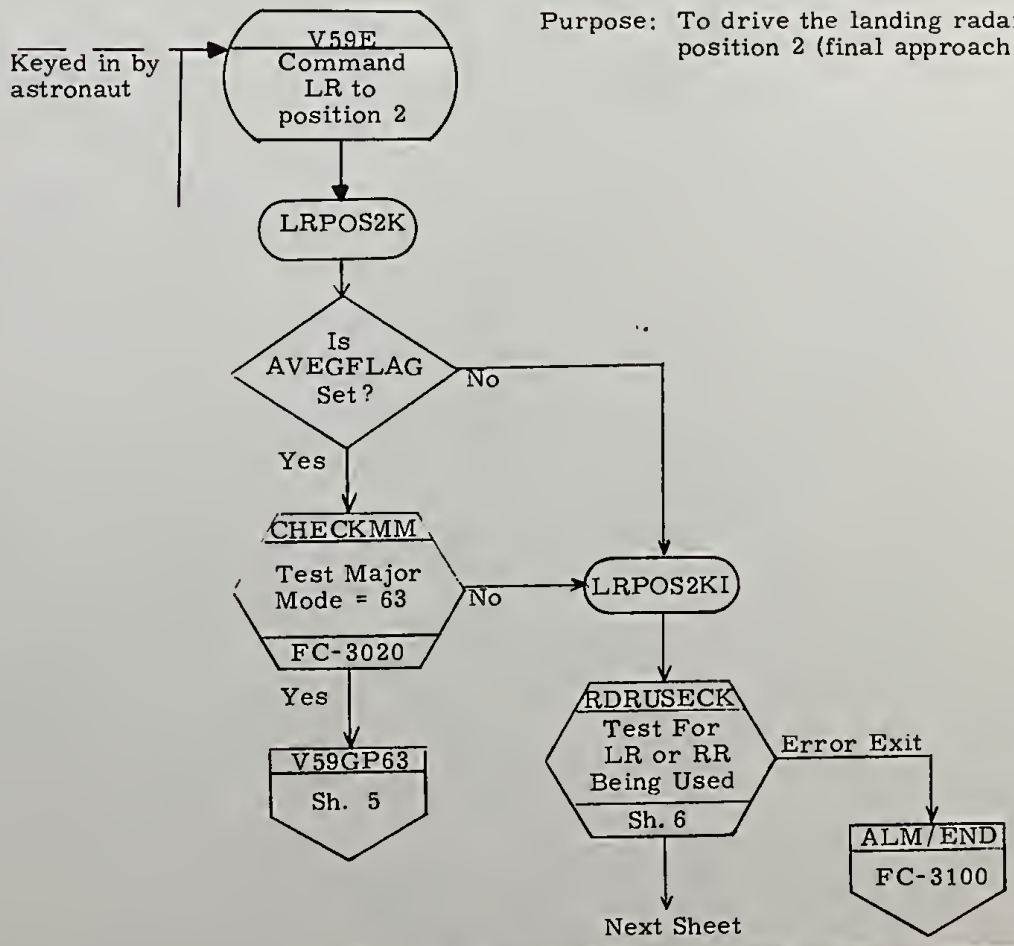


Purpose: To inhibit the incorporation of landing radar data during descent state vector update

Landing radar updates inhibited by astronaut

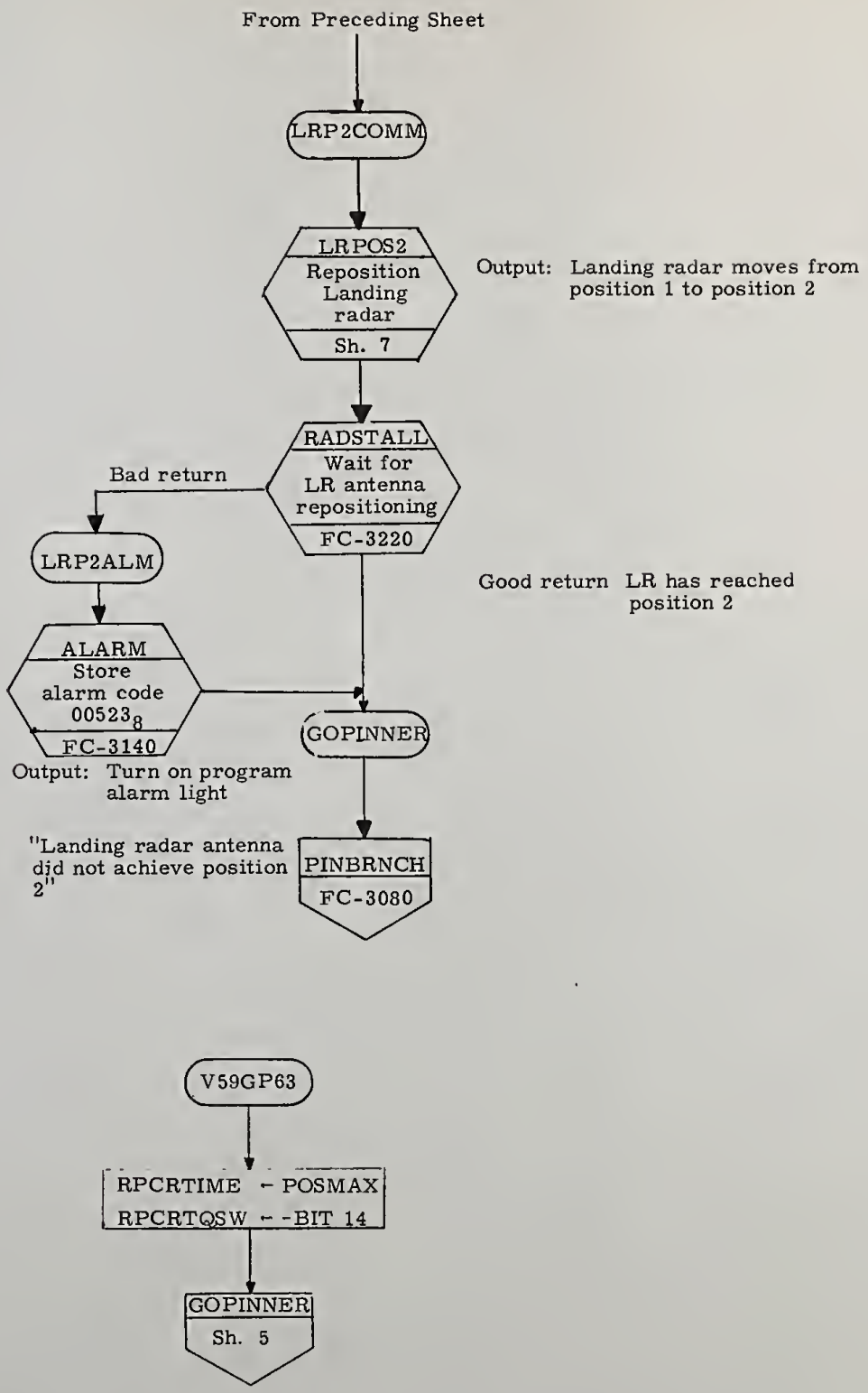
Exit via GOPIN

EXTENDED VERB 59

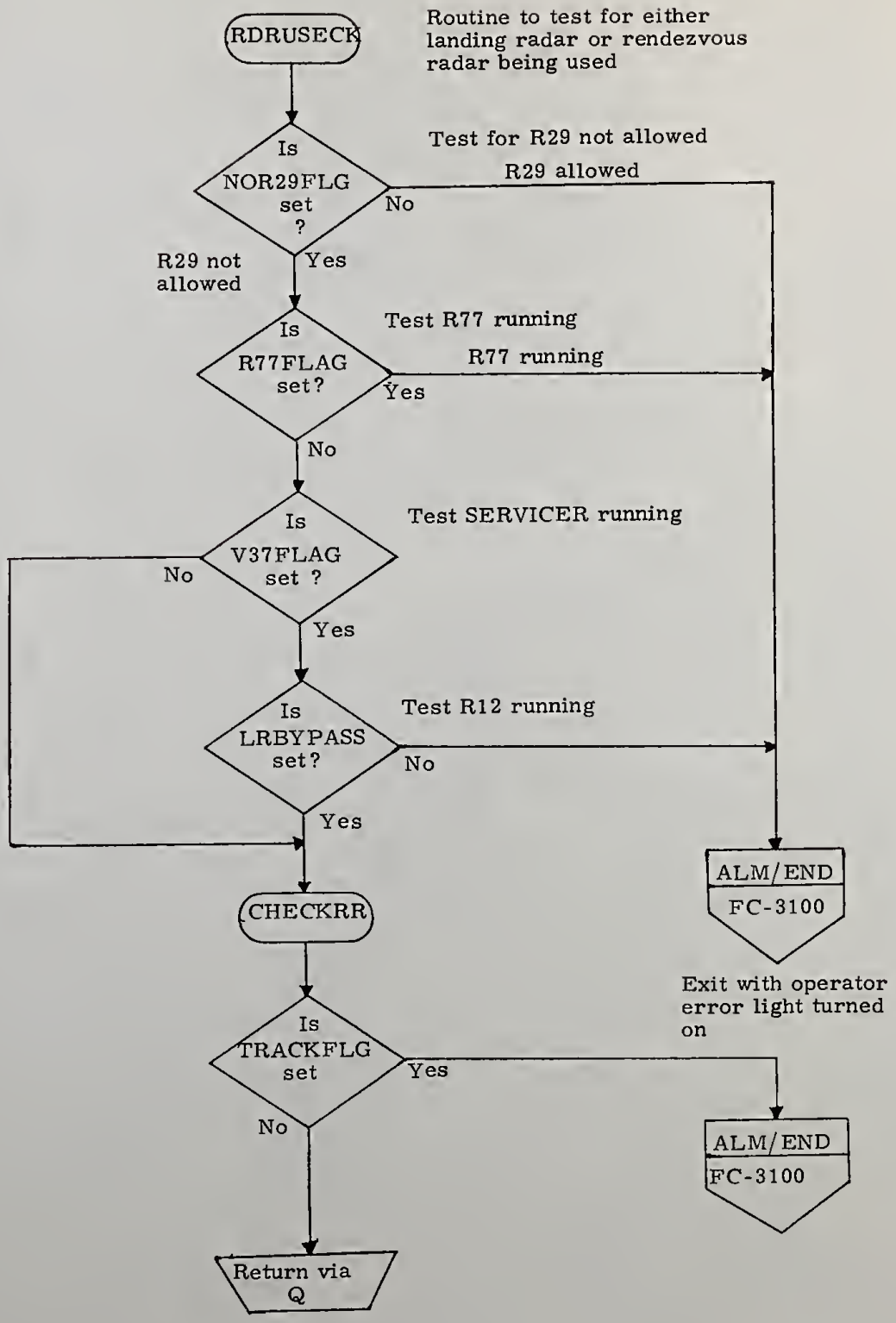


Purpose: To drive the landing radar to position 2 (final approach)

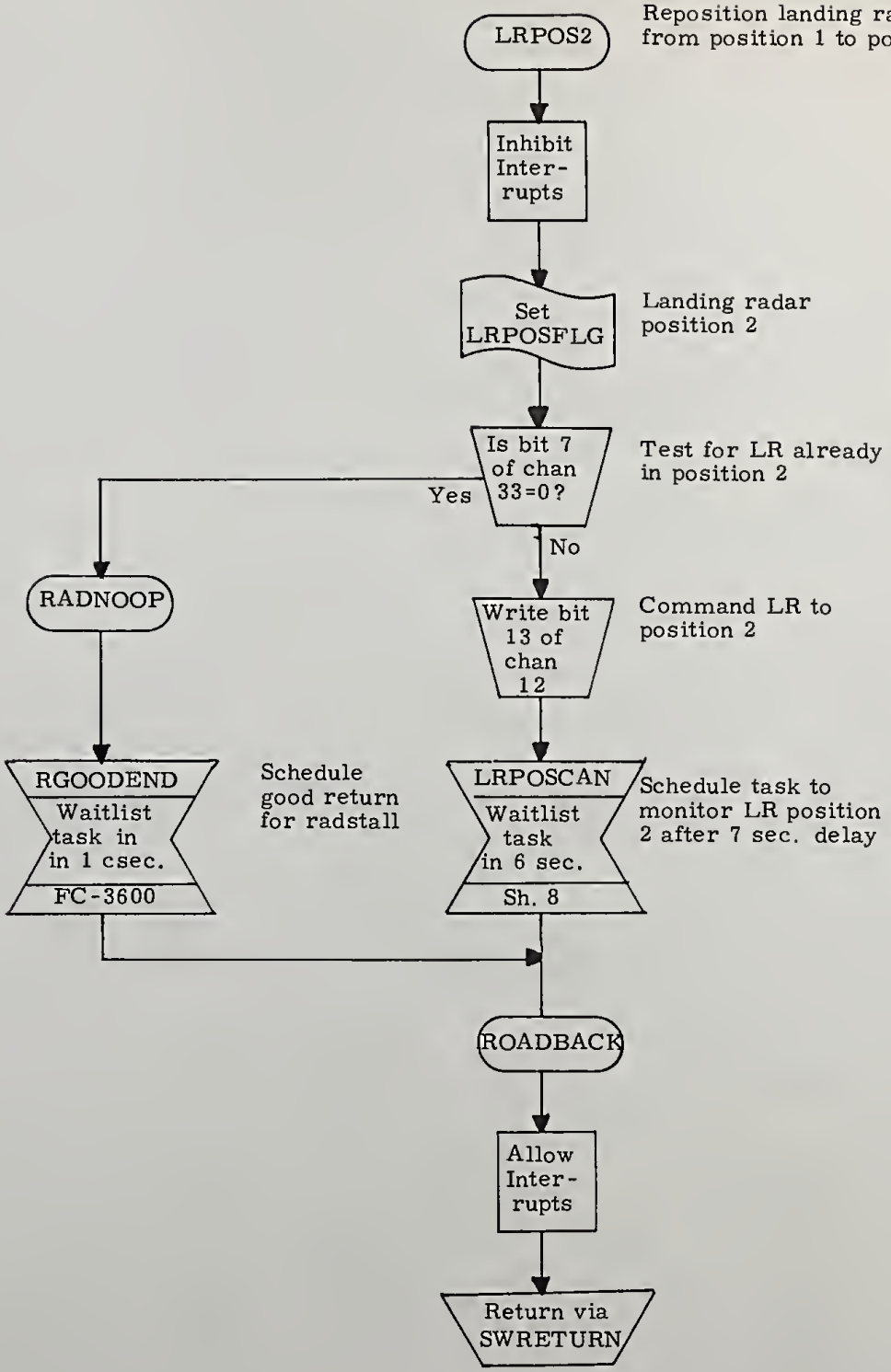
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN R. Welsh	12/4/69	R12 - Descent State Vector Update	
PRGMR D. Moore	12/6/69		
ANALST		LUMINARY 1C	DOCUMENT NO. FC-3935
DOCMR W. Danforth	12/9/69		
APPR'D Roberta M. Scott	12/11/69	REV 0	SHEET 4 OF 36



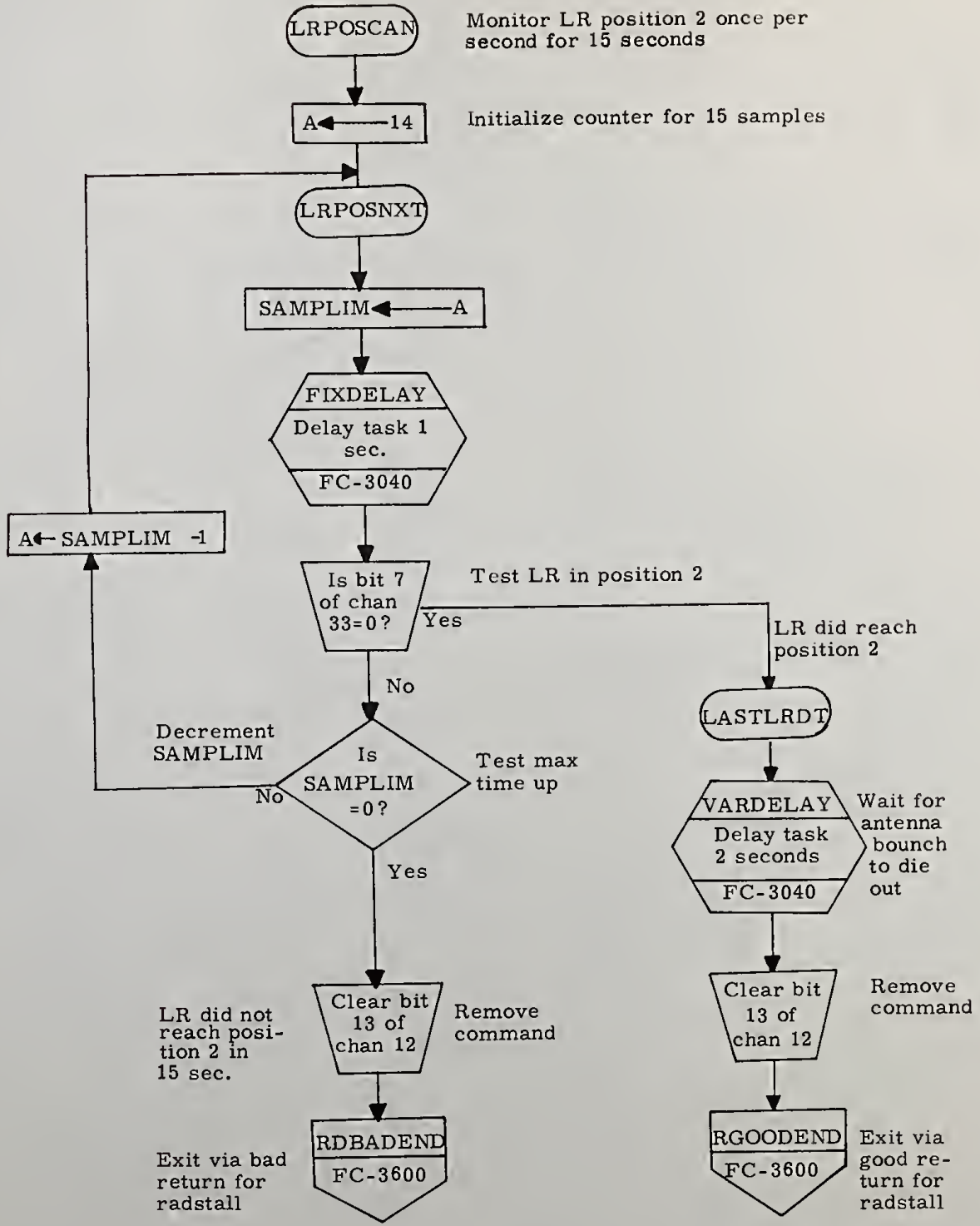
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.			APOLLO GUIDANCE AND NAVIGATION	
DRAWN	R. Welch	12/8/69	R12 - Descent State Vector Update	
PRGMR	D. Moore	12/1/69		
ANALST				DOCUMENT NO.
DOCMR	W. Duffett	12/9/69	LUMINARY 1C	FC-3935
APPR'D	Robert M. Eaton	12/1/69	REV 0	SHEET 5 OF 36



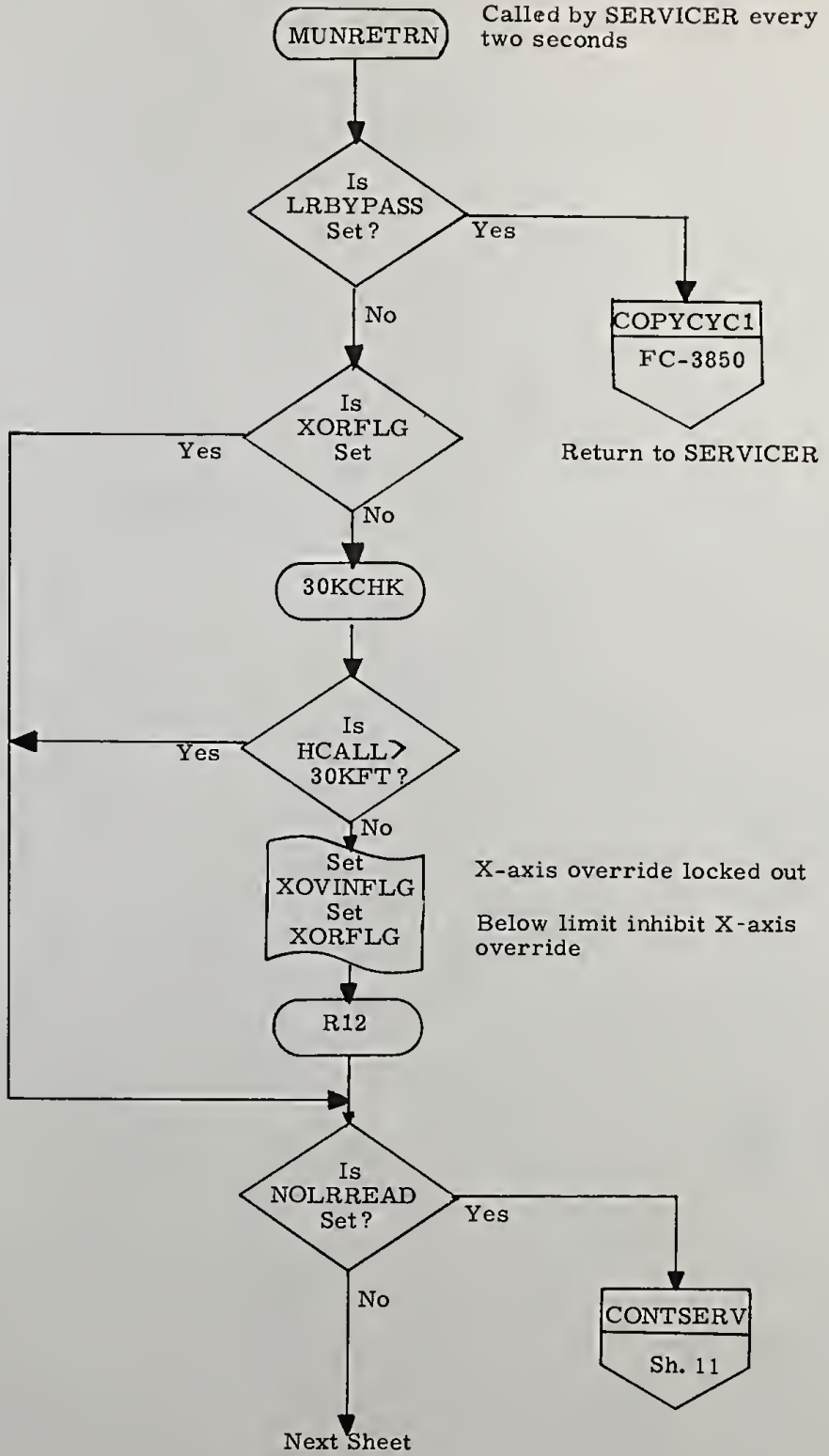
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	10/29/68	R12 - Descent State Vector Update	
PRGMR D. Moore	12/1/69	LUMINARY 1C	DOCUMENT NO. FC-3935
ANALST			
DOCMR	1/29/69	REV 0	SHEET 6 OF 36
APPR'D	12/1/69		



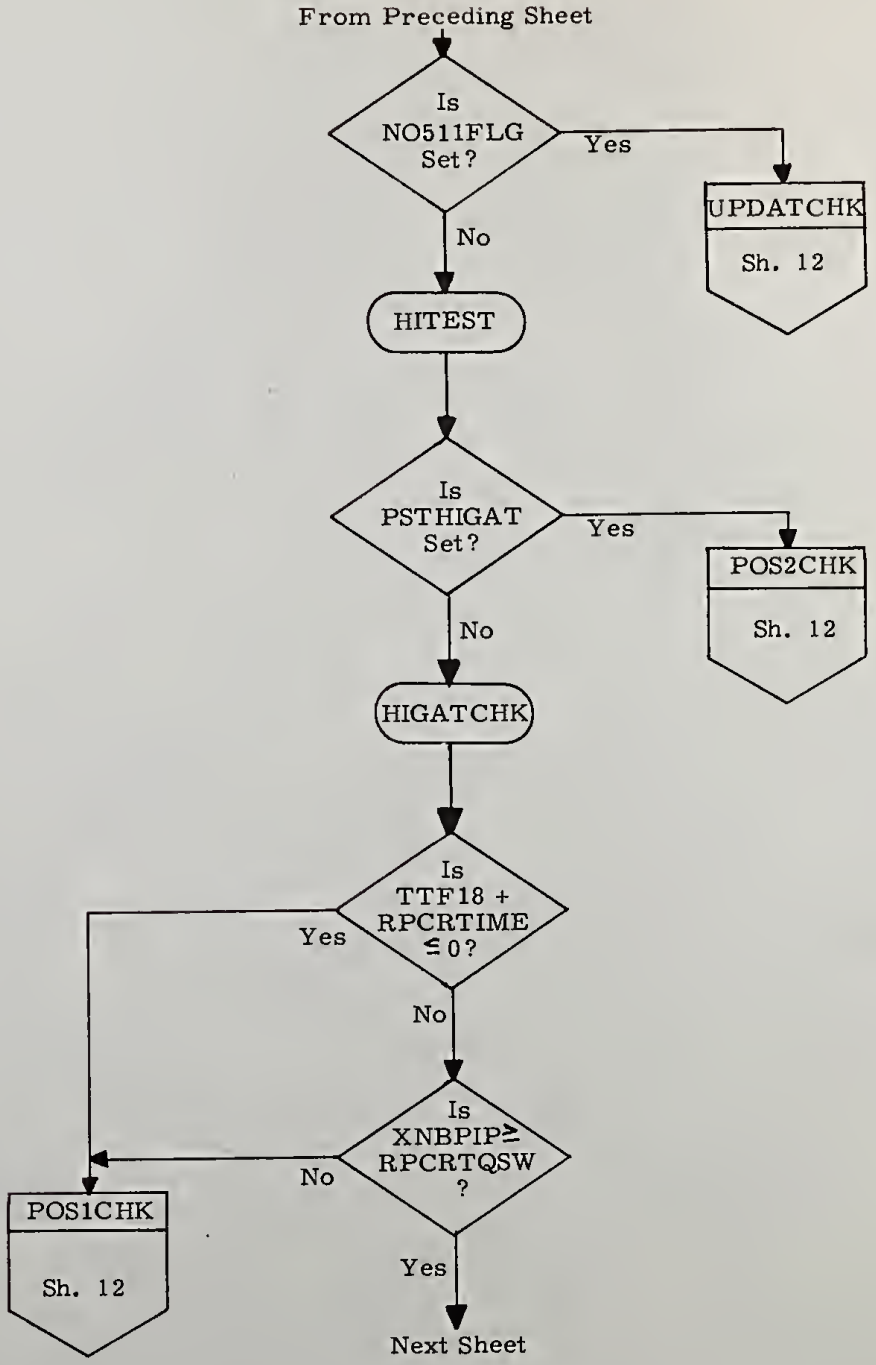
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		R12 - Descent State Vector Update	
PRGMR	12/1/69		
ANALST			DOCUMENT NO.
DOCMR	12/9/69	LUMINARY 1C	FC-3935
APPR'D	12/1/69	REV 0	SHEET 7 OF 36



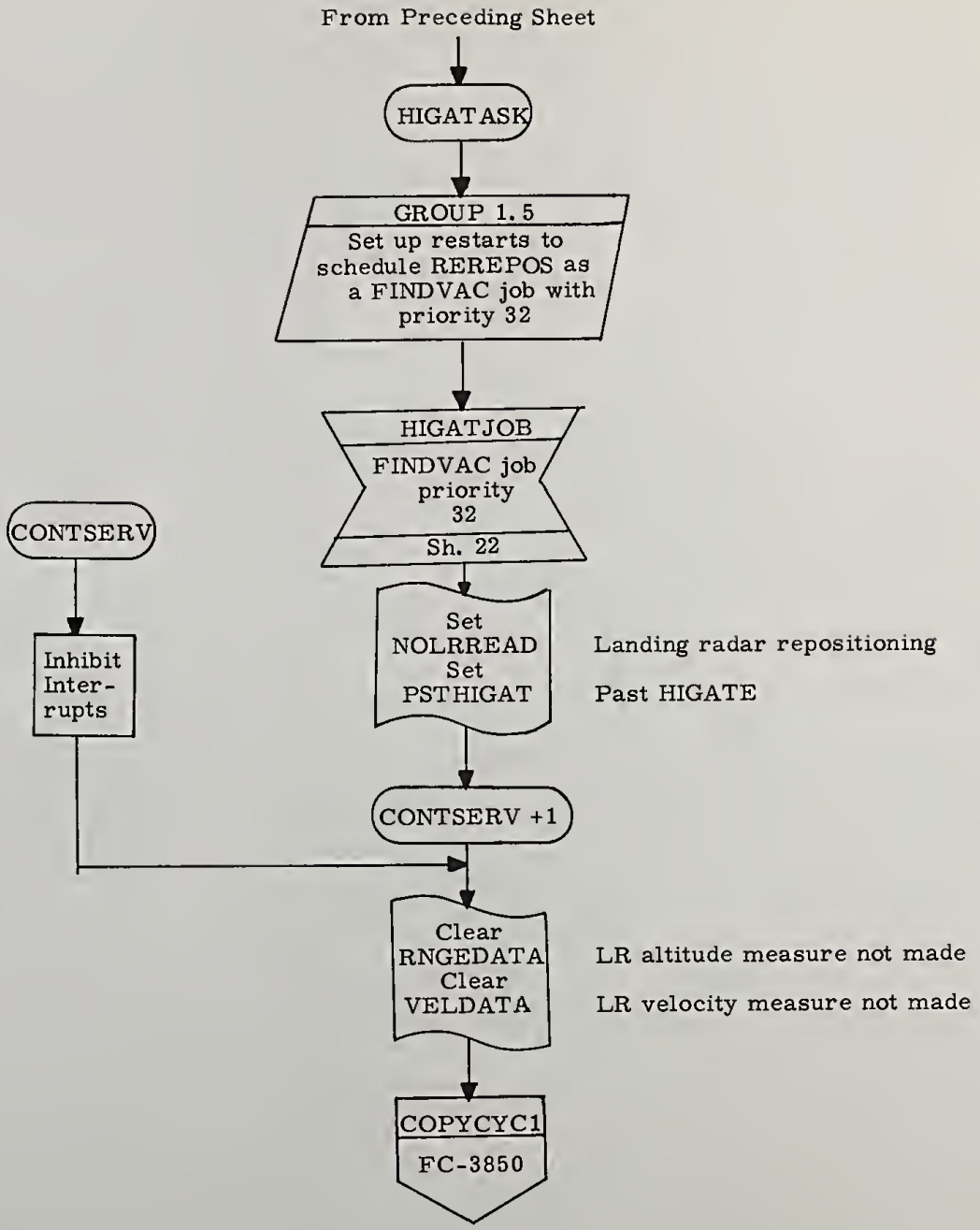
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN R. Welch	9/29/69	R12 - Descent State Vector Update	
PRGMR D. Moore	10/6/69		
ANALST		LUMINARY 1C	DOCUMENT NO. E-3935
DOCMR W. Duffett	10/29/69		
APPR'D R.M. Eyles	12/1/69	REV 0	SHEET 8 OF 36



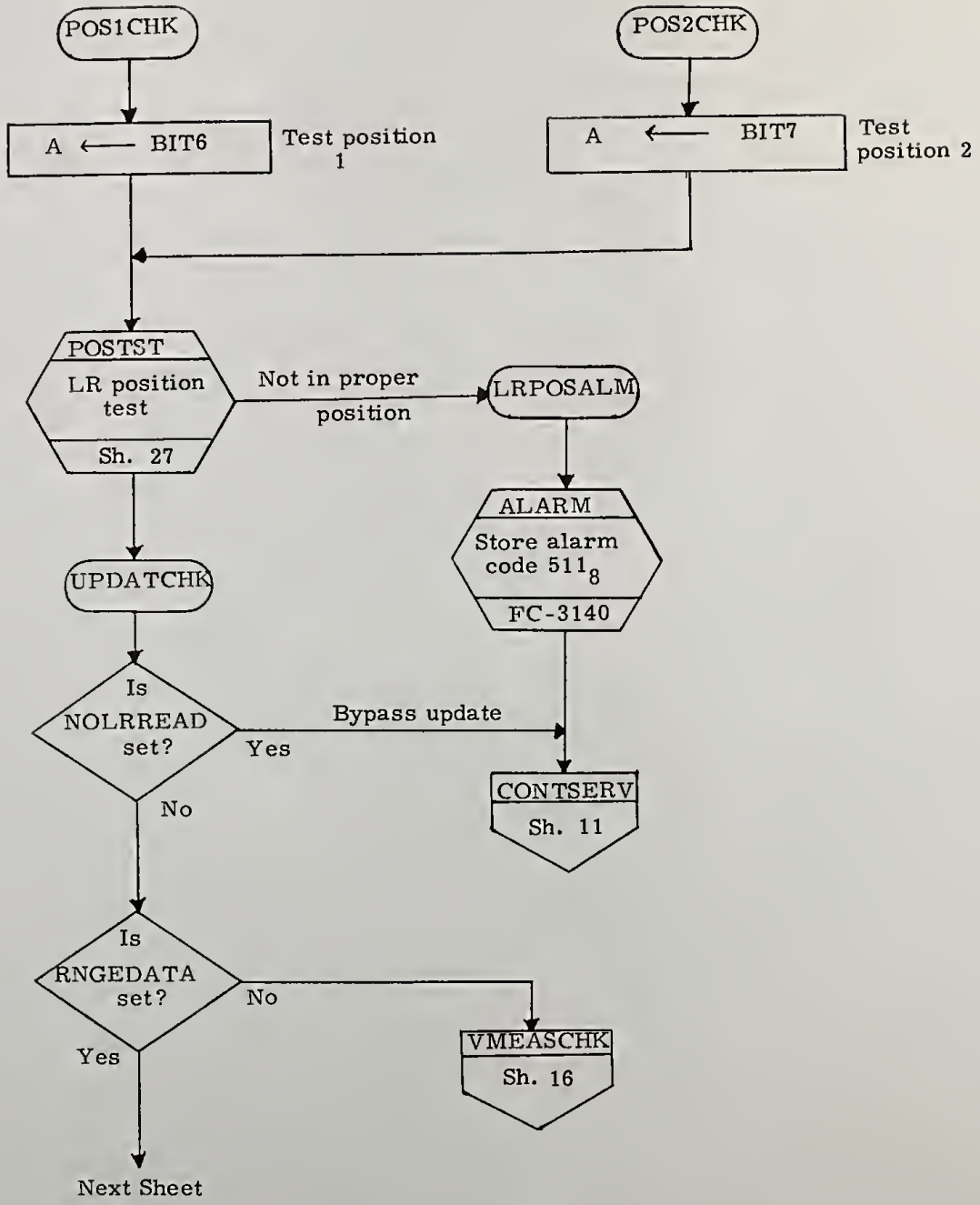
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN R. Wyloh	9/19/69	R12 - Descent State Vector Update	
PRGMR D. Moore	9/1/69		
ANALST		LUMINARY 1C	DOCUMENT NO. FC-3935
DOCMR W. Duffeth	11/04/69		
APPR'D R.M. Eyles	12/1/69	REV 0	SHEET 9 OF 36



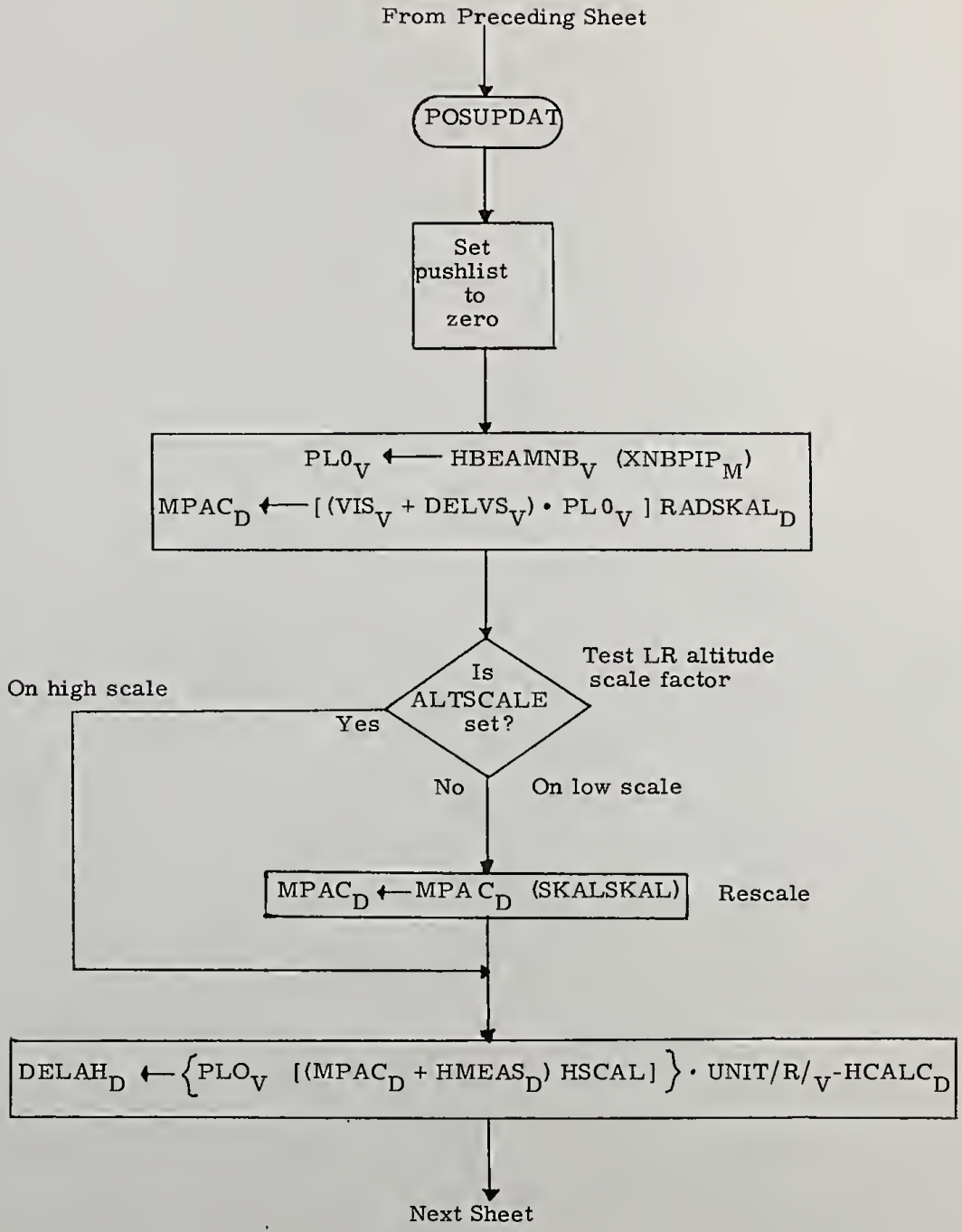
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	12/29/68	R12 - Descent State Vector Update	
PRGMR	12/1/69		
ANALST		LUMINARY 1C	DOCUMENT NO. 2C-3935
DOCMR	12/30/69		
APPR'D	12/11/69	REV 0	SHEET 10 OF 36



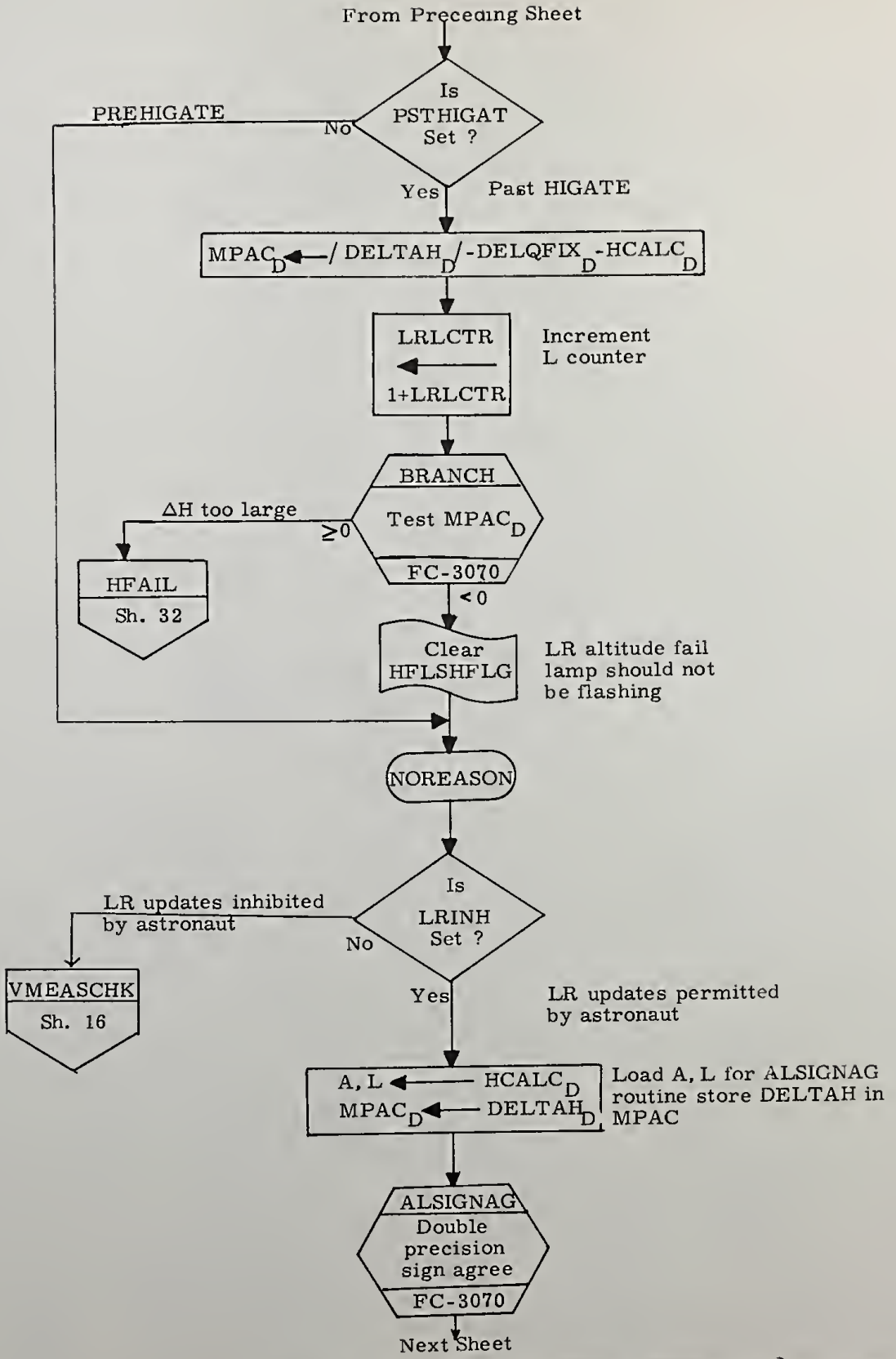
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN R. Welch	12/8/69	R12 - Descent State Vector Update	
PRGMR D. Moore	12/1/69		
ANALST		LUMINARY 1C	DOCUMENT NO. EC-3935
DOCMR W Dunford	12/9/69	REV 0	SHEET 11 OF 36
APPR'D R.M. Eyles	12/11/69		



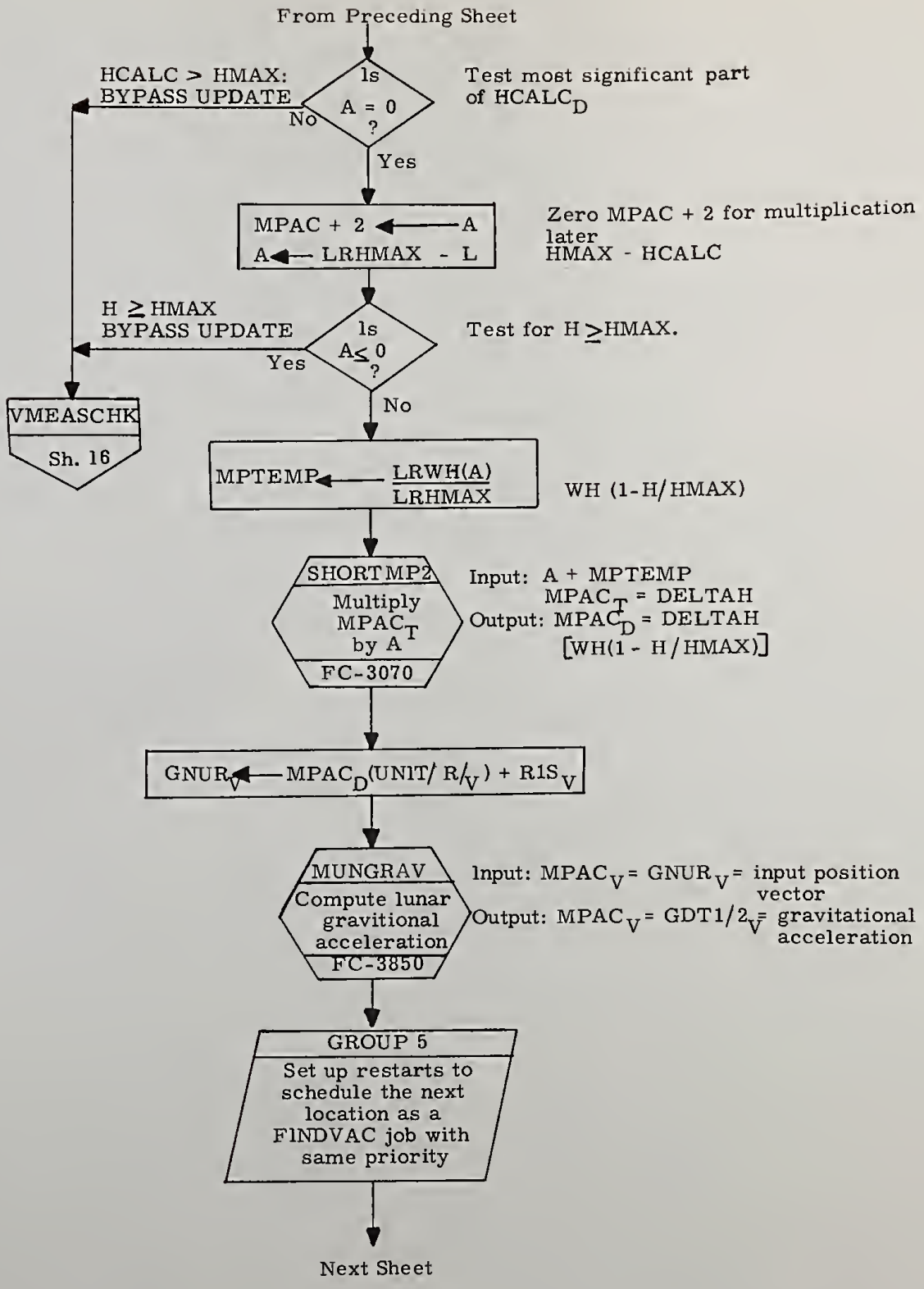
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN E. Welch	10/29/69	R12 - Descent State Vector Update	
PRGMR D. Moore	12/1/69	LUMINARY 1C	DOCUMENT NO. 2C-3935
ANALST			
DOCMR W. Digiovanni	11/30/69		
APPR'D R. M. Eyles	12/1/69	REV 0	SHEET 12 OF 36



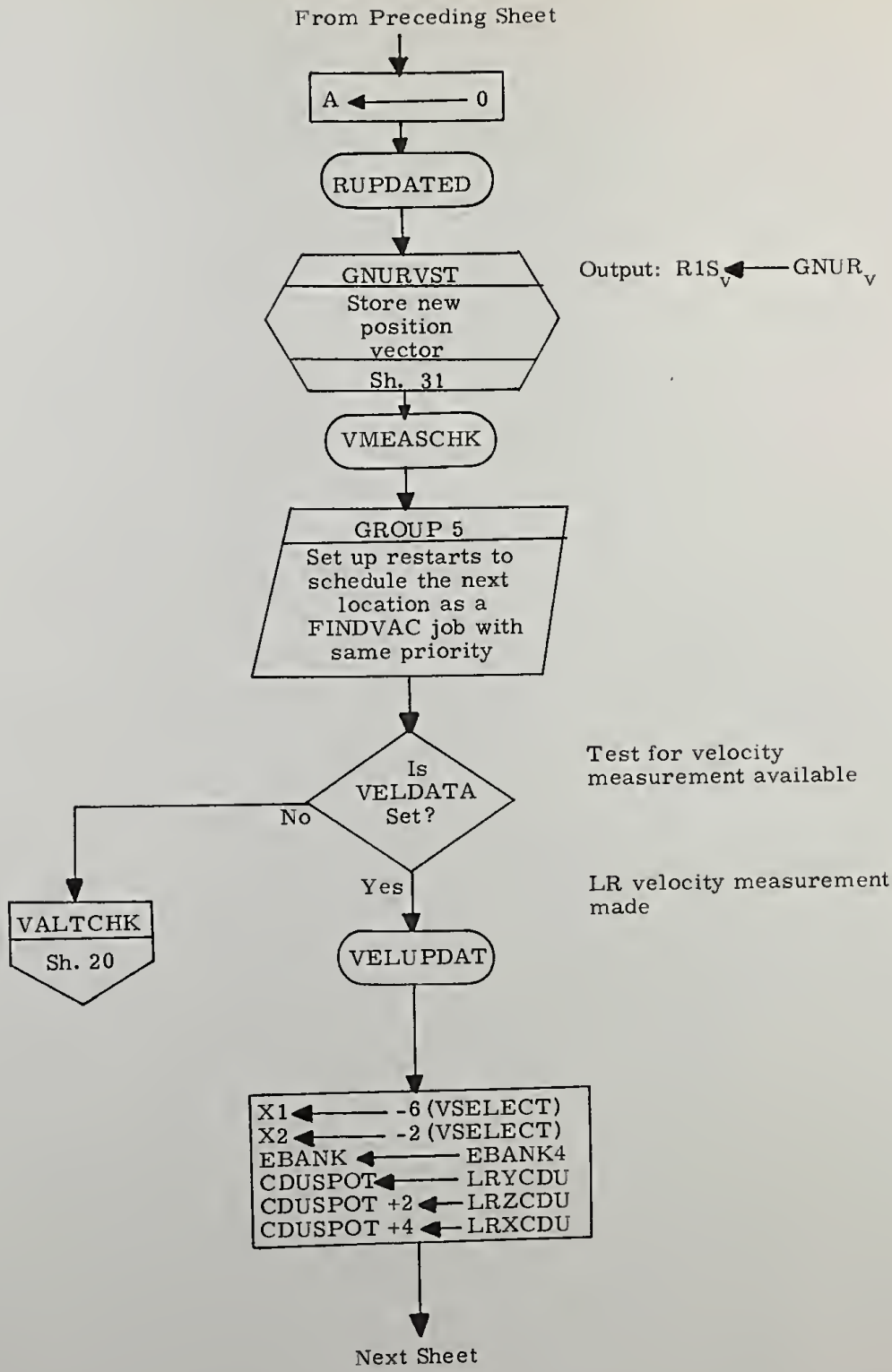
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN G. Wilson	12/2/69	R12 - Descent State Vector Update	
PRGMR D. Moore	12/1/69		
ANALST		LUMINARY 1C	DOCUMENT NO. FC-3935
DOCMR W. Bybee	12/5/69		
APPR'D R.M. Eyles	12/1/69	REV 0	SHEET 13 OF 36



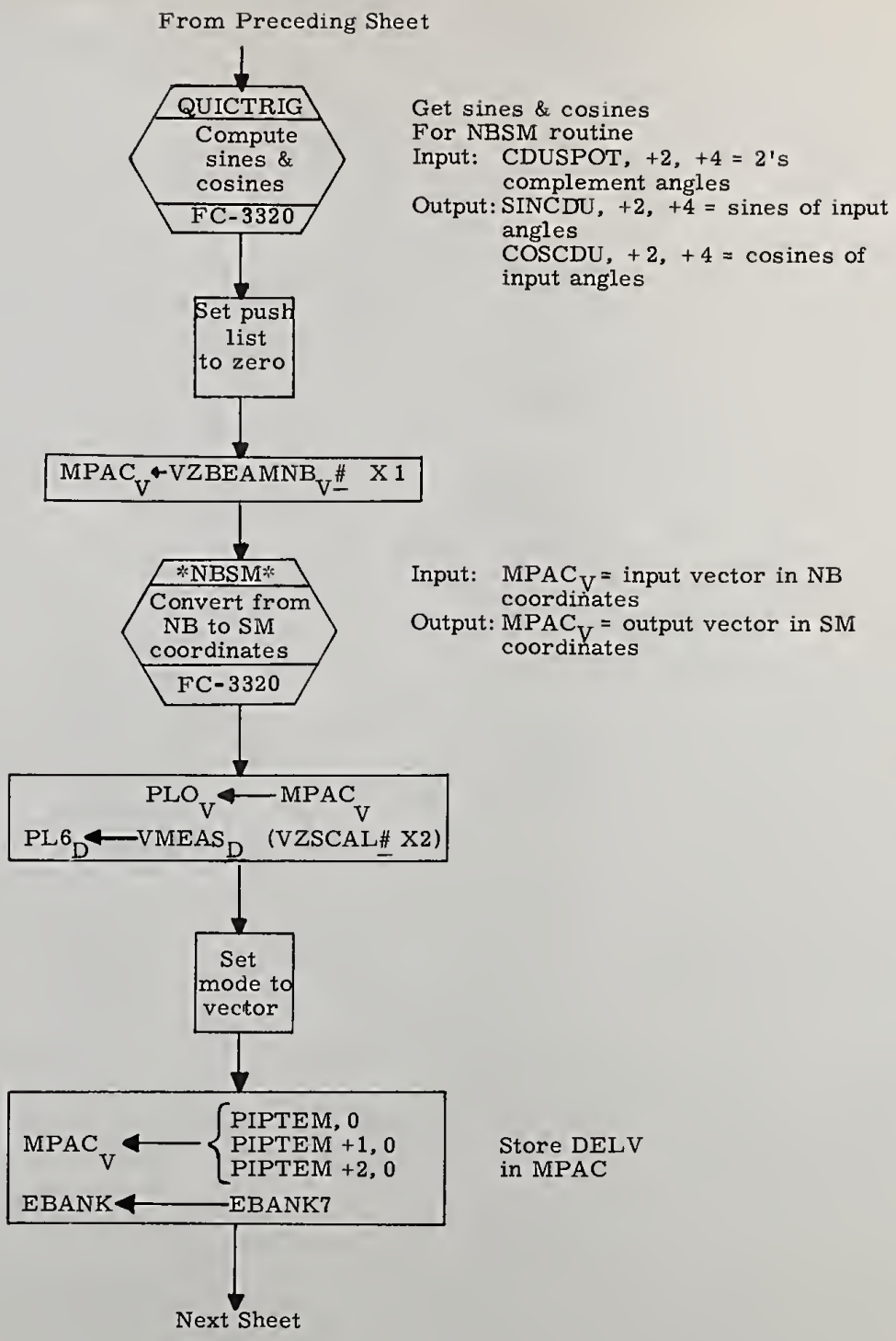
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN R. Welch	10/29/68	R12 - Descent State Vector Update	
PRGMR D. Moore	12/1/69		
ANALST		LUMINARY 1C	DOCUMENT NO. FC-3935
DOCMR W. Dogherty	10/29/69		
APPR'D R. M. Eyles	12/1/69	REV 0	SHEET 14 OF 36



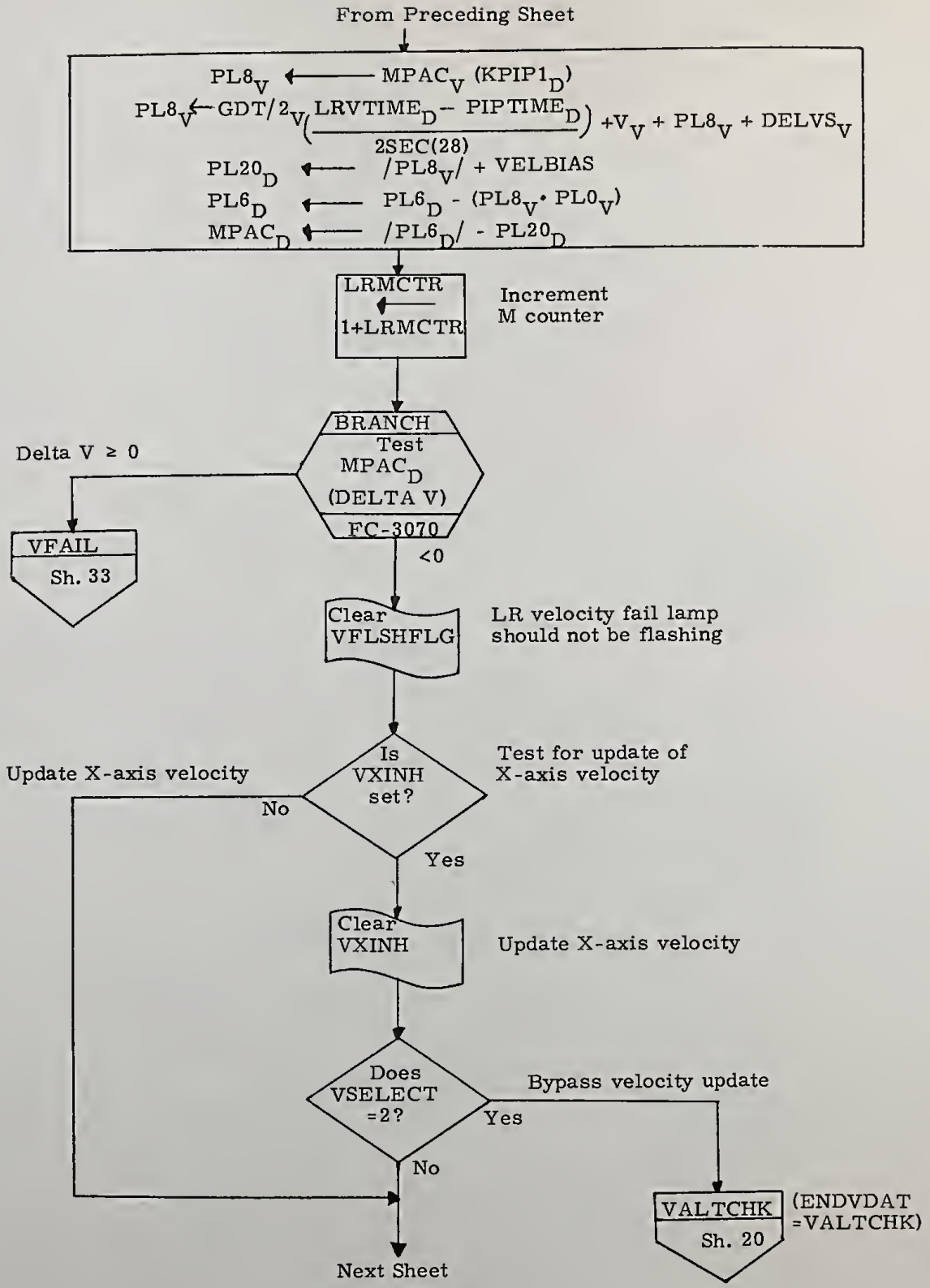
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN R. Welch	10/3/68	R12 - Descent State Vector Update	
PRGMR D Moore	1/4/69		
ANALST		LUMINARY 1C	DOCUMENT NO. FC-3935
DOCMR W Dryfoos	1/29/69		
APPR'D R.M. Eyles	12/1/69	REV 0	SHEET 15 OF 36



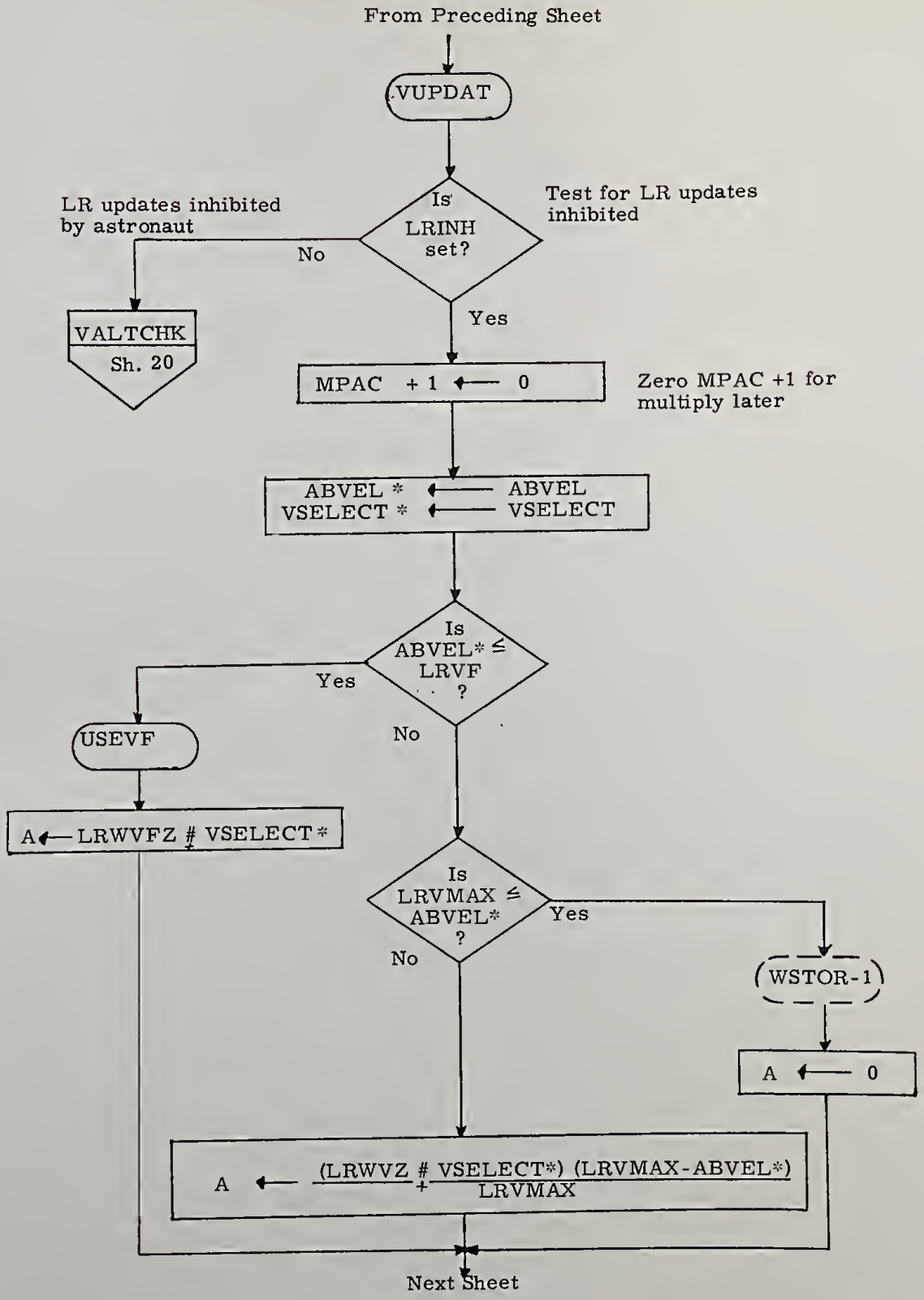
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN R. Welch	10/23/69	R12 - Descent State Vector Update	
PRGMR D. Moore	12/1/69		DOCUMENT NO.
ANALST		LUM 3, 1C	MC-3935
DOCMR W. Dyghuis	11/24/69		
APPR'D R.M. Eyles	12/1/69	REV 0	SHEET 1 OF 36



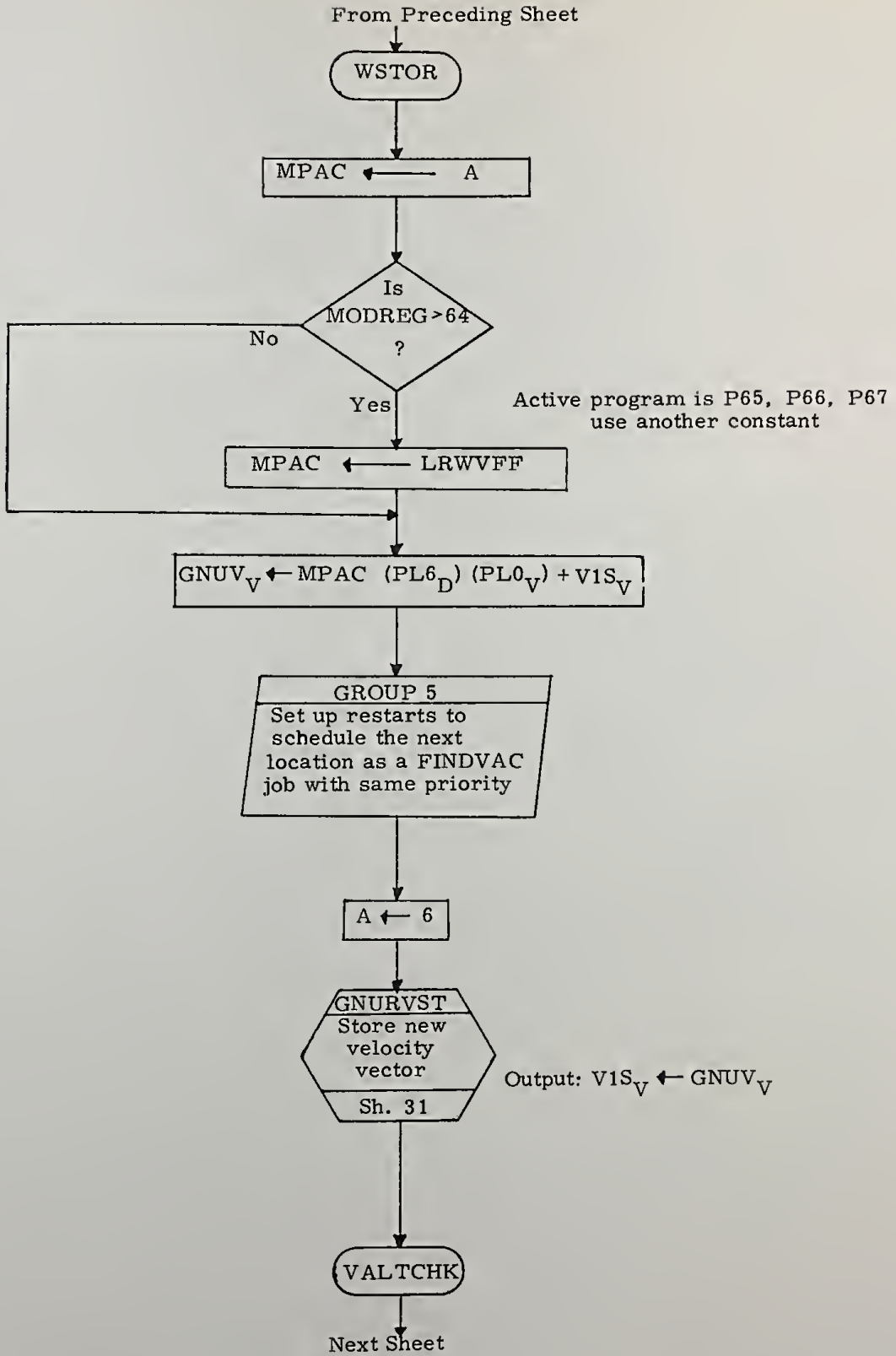
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN R. Welch	11/26/69	R12 - Descent State Vector Update	
PRGMR D. Moore	12/1/69		
ANALST			DOCUMENT NO.
DOCMR W. Dagbeth	12/3/69	LUMINARY 1C	FC-3935
APPR'D R. M. Eyles	12/1/69	REV 0	SHEET 17 OF 36



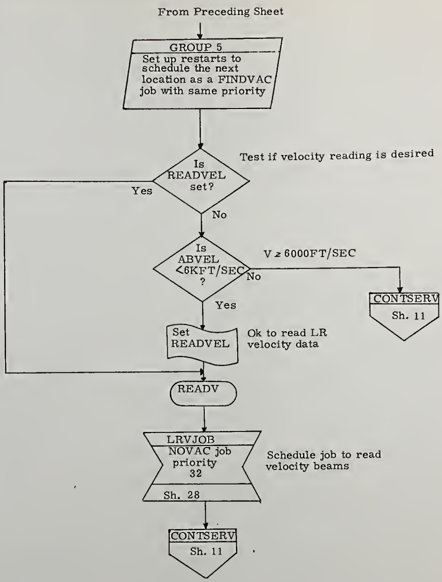
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN G. Welch	10/23/68	R12 - Descent State Vector Update	
PRGMR D. Moore	12/1/69		
ANALST		LUMINARY 1C	DOCUMENT NO. FC-3935
DOCMR W. Bigbee	11/3/69		
APPR'D R.M. Eyles	12/1/69	REV 0	SHEET 18 OF 36



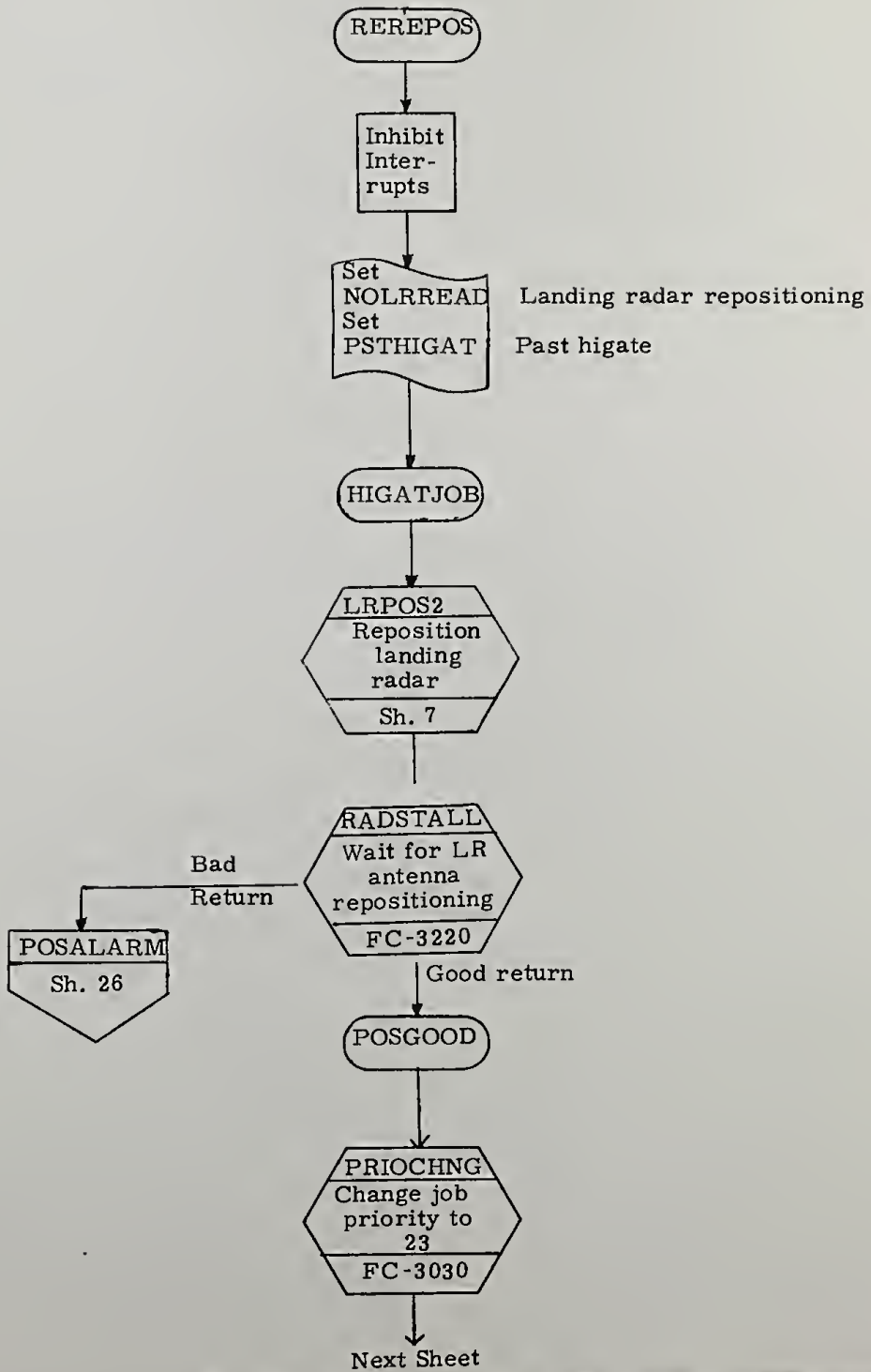
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN G Welch	10/23/69	R12 - Descent State Vector Update	
PRGMR D Moore	10/6/69		
ANALST		LUMINARY 1C	DOCUMENT NO. FC-3935
DOCMR W Boyd	10/29/69	REV 0	SHEET 19 OF 36
APPR'D	11/1/69		



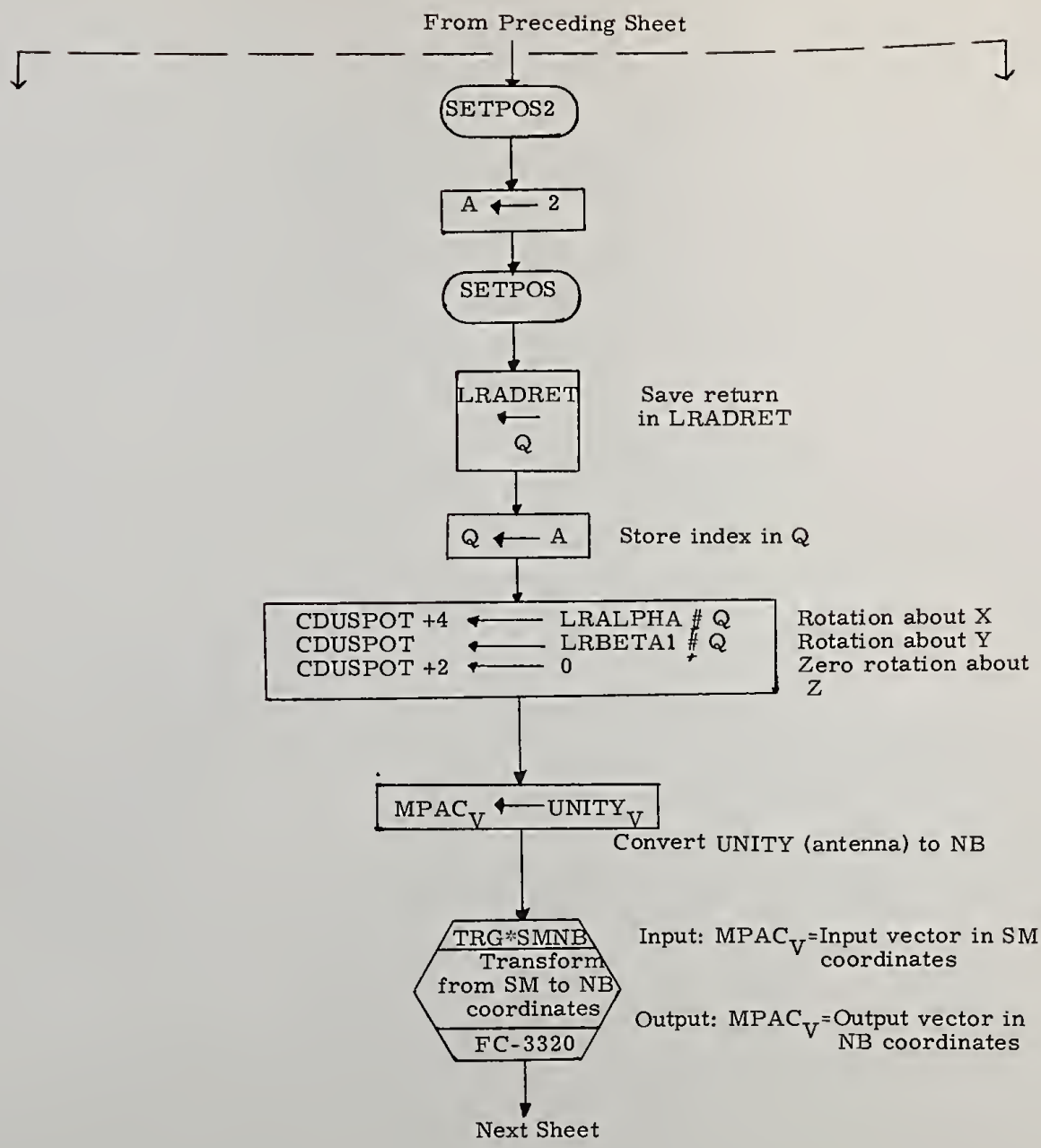
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	10/25/69	R12 - Descent State Vector Update	
PRGMR	12/1/69		
ANALST		LUMINARY 1C	DOCUMENT NO. E-3935
DOCMR	1/13/69		
APPR'D	12/1/69	REV 0	SHEET 20 OF 36



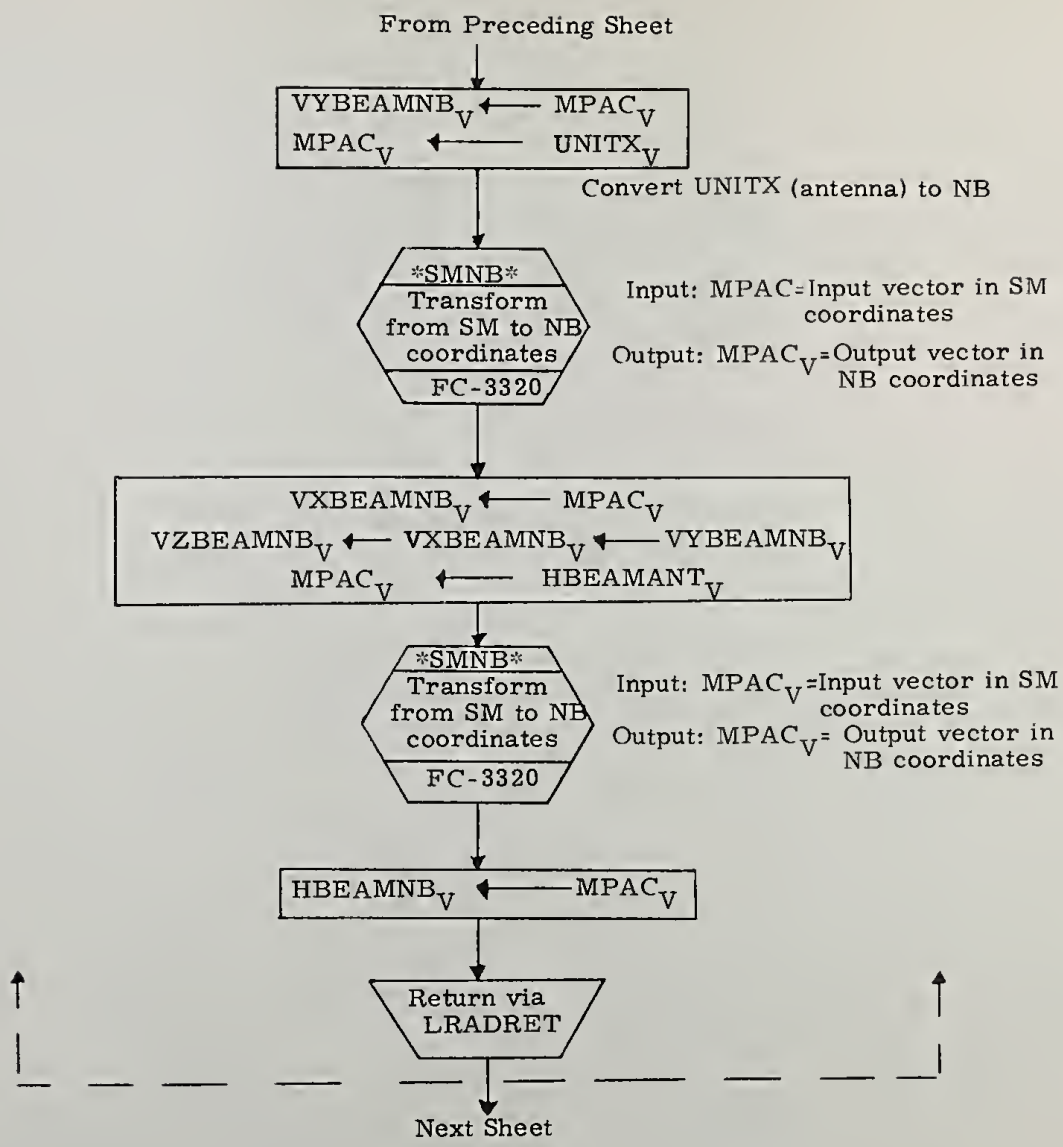
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN *G. Lietch*	11/03/69	R12 - Descent State Vector Update	
PRGMR *D Moore*	12/1/69	LUMINARY 1C	DOCUMENT NO. FC-3935
ANALST			
DOCMR *[illegible]*	10/30/69		
APPR'D *[illegible]*	12/1/69	REV 0	SHEET 21 OF 36



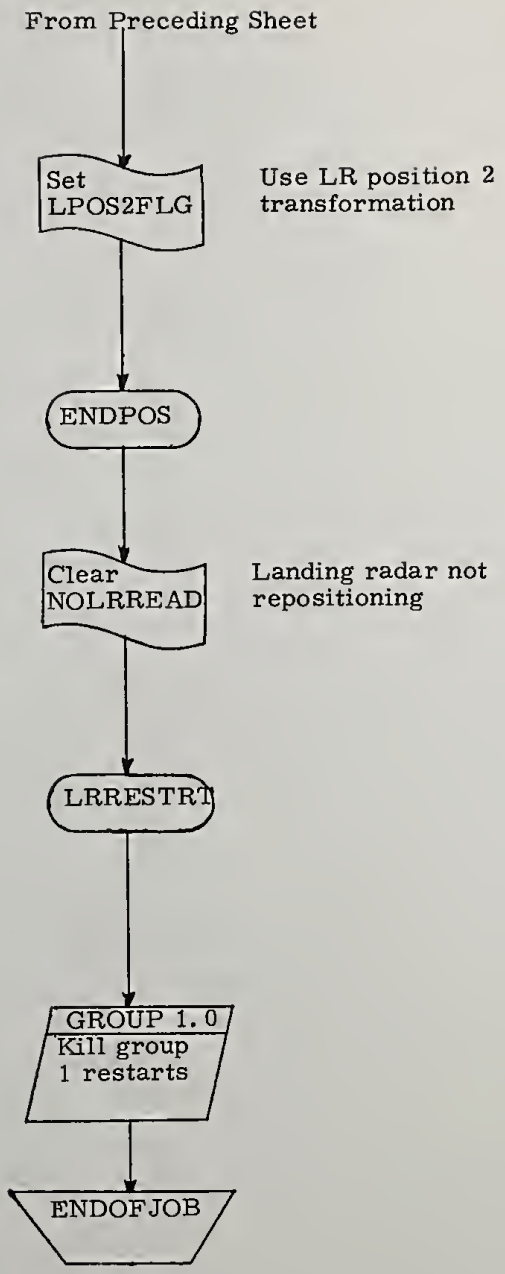
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN R. Walker	10/29/69	R12 - Descent State Vector Update	
PRGMR D. Moore	12/1/69		DOCUMENT NO.
ANALST		LUMINARY 1C	FC-3935
DOCMR M. Dagbolt	12/3/69		
APPR'D R.M. Eyles	12/1/69	REV 0	SHEET 220F 36



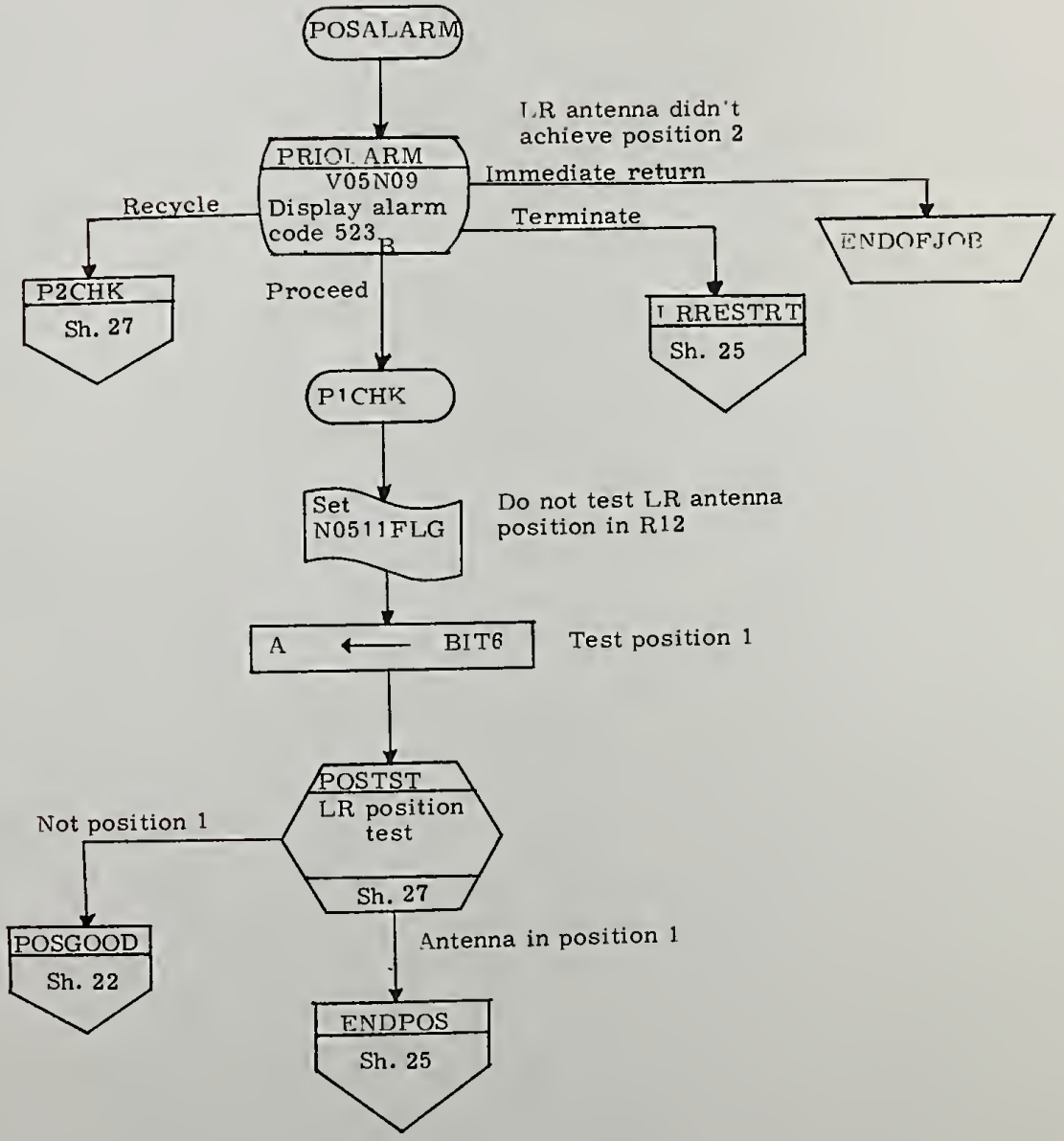
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN R Welch	10/23/69	R12 - Descent State Vector Update	
PRGMR D Moore	12/1/69		
ANALST		LUMINARY 1C	DOCUMENT NO. FC-3935
DOCMR W Hyatt	12/3/69		
APPR'D R M Eyles	12/1/69	REV 0	SHEET 23 OF 36



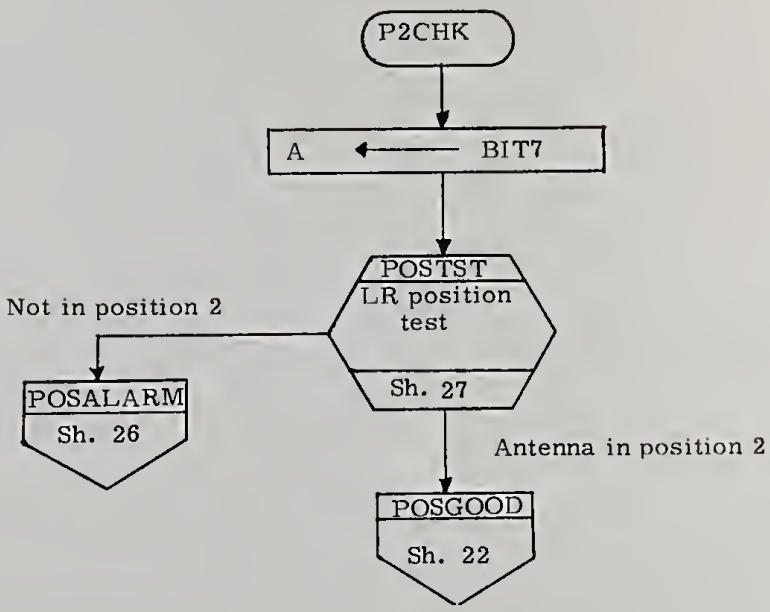
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	10/23/69	R12 - Descent State Vector Update	
PRGMR	12/1/69	LUMINARY 1C	DOCUMENT NO. FC-3935
ANALST			
DOCMR	10/24/69		
APPR'D	12/1/69	REV 0	SHEET 24 OF 36

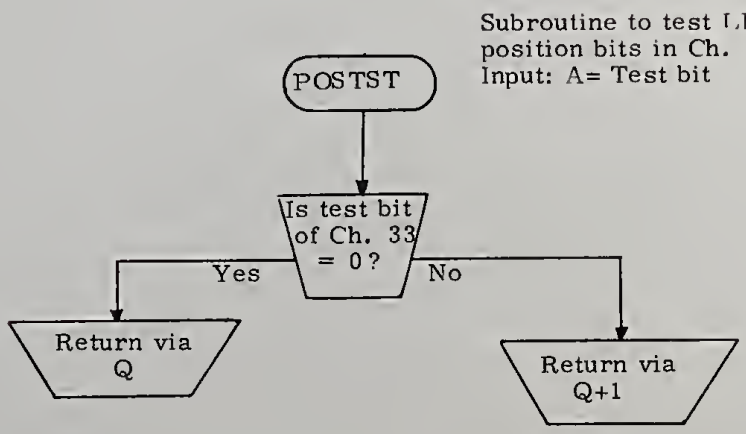


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	12/2/69	R12 - Descent State Vector Update	
PRGMR	12/1/69		
ANALST		LUMINARY 1C	DOCUMENT NO. FC-3935
DOCMR	12/3/69		
APPR'D	12/1/69	REV 0	SHEET 25 OF 36

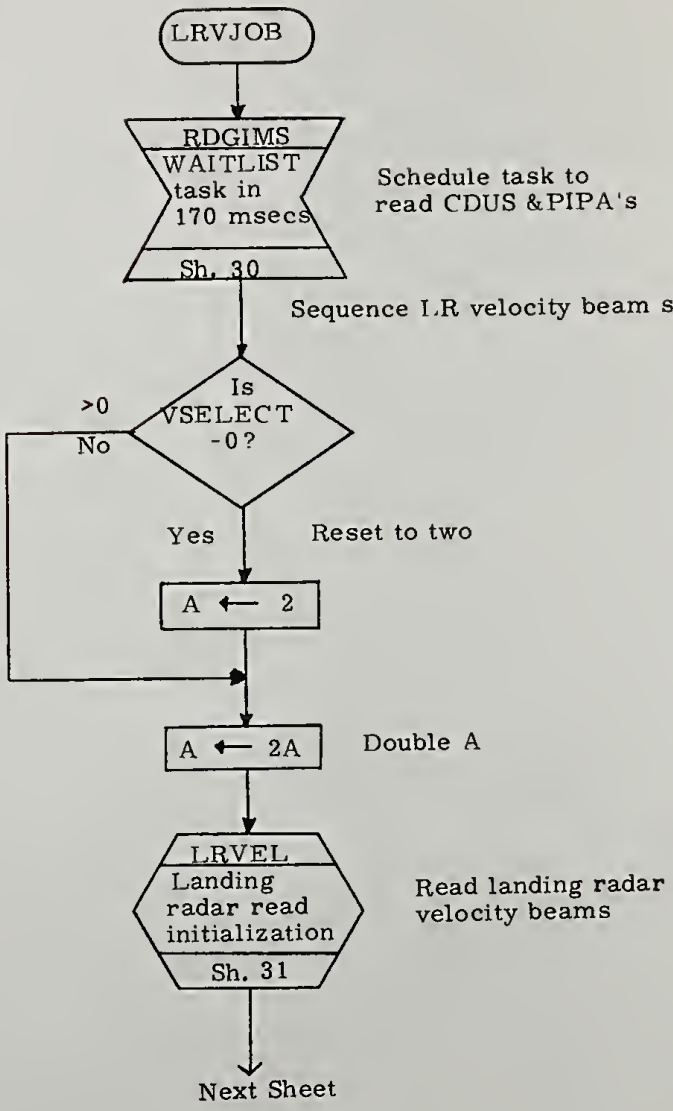


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN R. Welch	10/29/69	R12 - Descent State Vector Update	
PRGMR D Moore	12.1.69		
ANALST		LUMINARY 1C	DOCUMENT NO. FC-3935
DOCMR M Daigneault	10/30/69		
APPR'D R M Eyles	12/1/69	REV 0	SHEET 26 OF 36

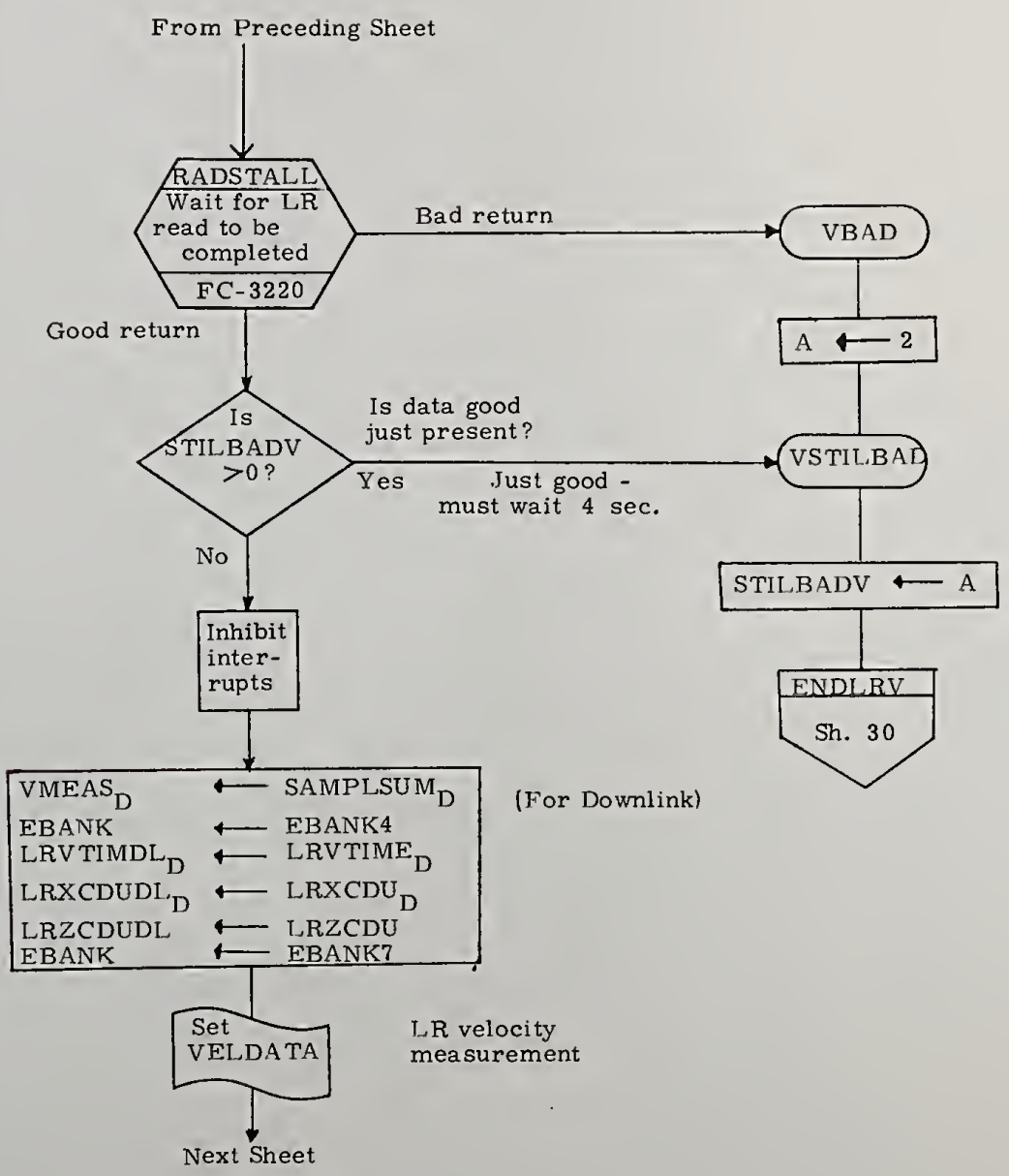




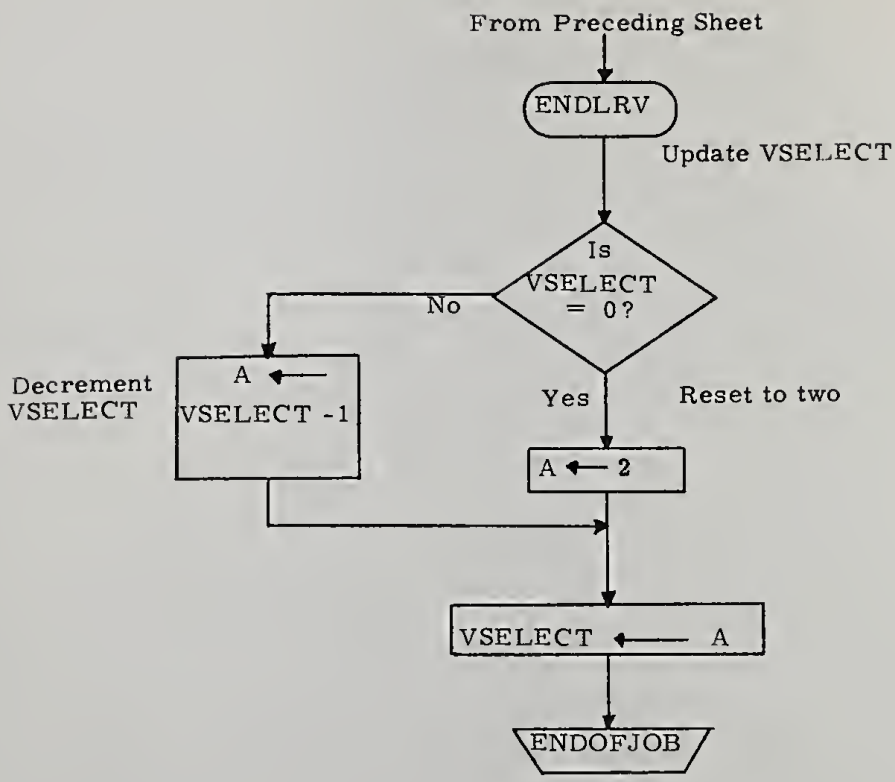
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	11/23/69	R12 - Descent State Vector Update	
PRGMR	12/1/69		
ANALST			
DOCMR	11/24/69		
APPR'D	12/1/69	RI 0	SHEET 2 OF 36

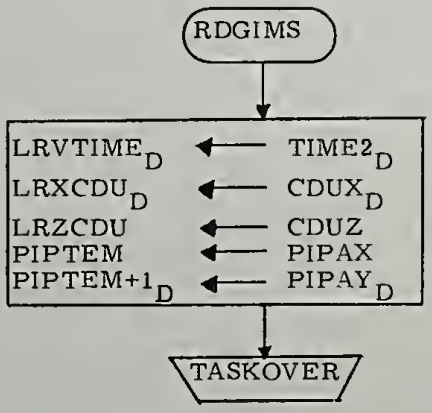


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN R. Welch	11/26/69	R12 - Descent State Vector Update	
PRGMR D. Moore	12/1/69		
ANALST		LUMINARY 1C	DOCUMENT NO. FC-3935
DOCMR W. Duffett	11/26/69		
APPR'D R.M. Eyles	12/1/69	REV 0	SHEET 28 OF 36

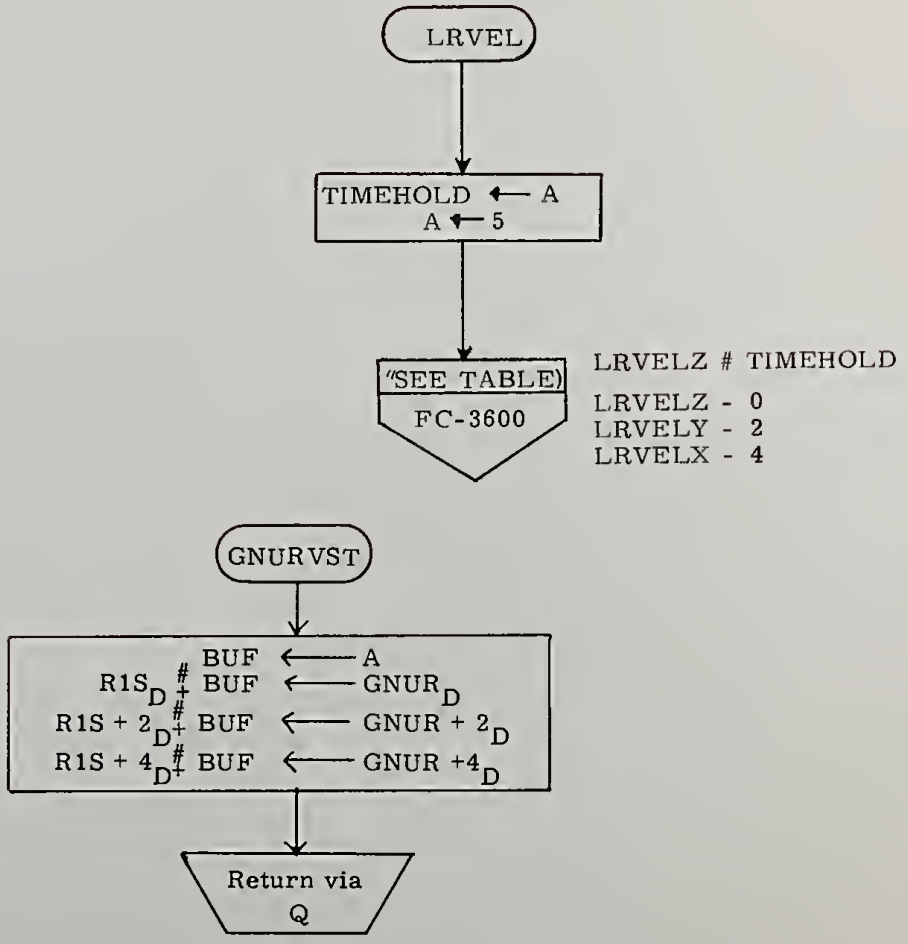


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	12/9/69	R12 - Descent State Vector Update	
PRGMR	12/1/69		
ANALST		LUMINARY 1C	DOCUMENT NO. FC-3935
DOCMR	12/9/69		
APPR'D	12/1/69	REV 0	SHEET 29 OF 36

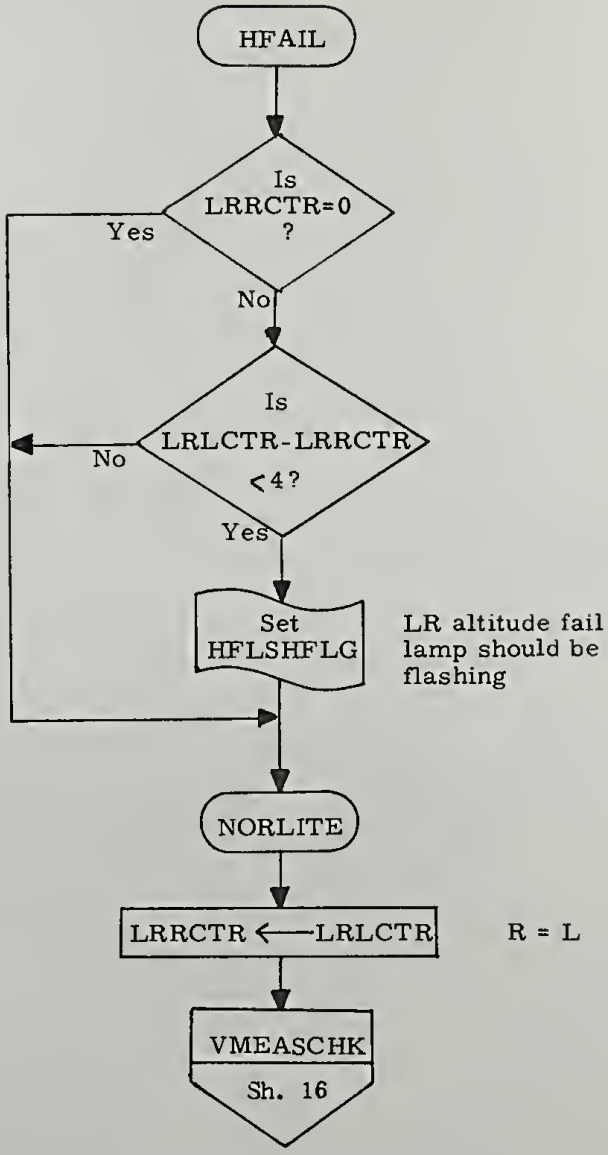




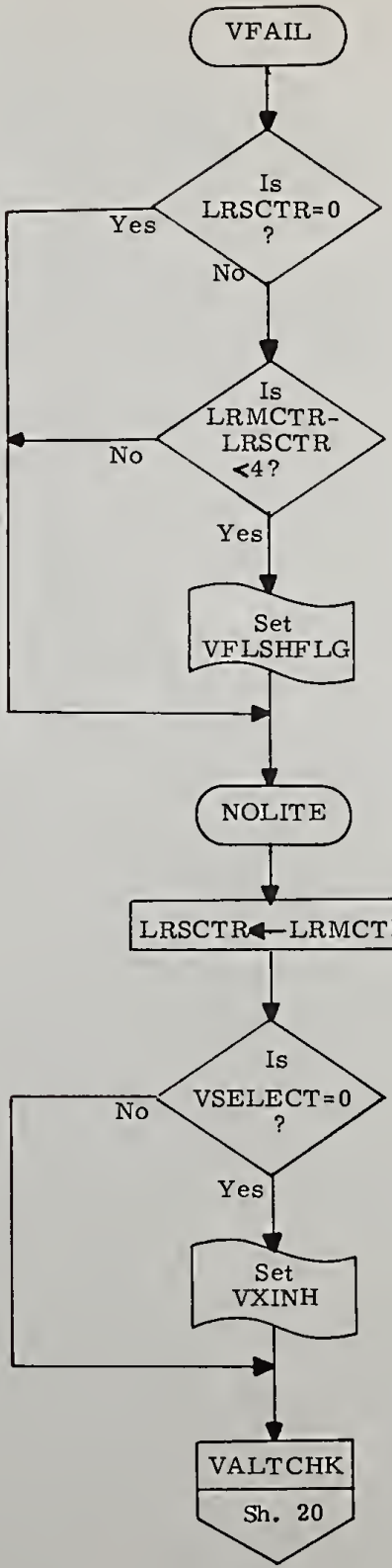
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN R. Welch	12/2/69	R12 - Descent State .Vector Update	
PRGMR D. Moore	12/1/69	LUMINARY 1C	DOCUMENT NO. FC-3935
ANALST			
DOCMR W. Bryant	12/2/69		
APPR'D R.M. Eyles	12/1/69	REV 0	SHEET 30 OF 36



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN R. Welch	9/29/69	R12 - Descent State Vector Update	
PRGMR D Moore	12/1/69		
ANALST		LUMINARY 1C	DOCUMENT NO. FC-3935
DOCMR W. Dayton	12/3/69		
APPR'D R M Eaton	12/3/69	REV 0	SHEET 31 OF 36



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN R. Welch	12/1/69	R12 - Descent State Vector Update	
PRGMR D. Moore	12/1/69		
ANALST		LUMINARY 1C	DOCUMENT NO. E[illegible]-3935
DOCMR M. Daggett	12/3/69		
APPR'D R M Eyles	12/1/69	REV 0	SHEET 32 OF 36



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN R. Welch	11/03/69	R12 - Descent State Vector Update	
PRGMR D Moore	12/1/69		
ANALST		LUMINARY 1C	DOCUMENT NO. FC-3935
DOCMR W Eyhart	12/3/69		
APPR'D RM Ewing	12/11/69	REV 0	SHEET 33 OF 36

Subroutine	Flowchart	Description	Where Called
TESTXACT	FC-3100	Test for extended verb active	Sh. 2
2SECDELY	FC-3050	Delay job 2 seconds	Sh. 3
RADSTALL	FC-3220	Wait for end of radar routine	Sh. 5, 22, 29
ALARM	FC-3140	Store alarm code	Sh. 5, 12
FIXDELAY	FC-3040	Delay task 1 second	Sh. 8
VARDELAY	FC-3040	Delay task 2 seconds	Sh. 8
BRANCH	FC-3070	Test $MPAC_D$	Sh. 14, 18
ALSIGNAG	FC-3070	Double precision sign agree	Sh. 14
SHORTMP2	FC-3070	Multiply $MPAC_T$	Sh. 15
MUNGRAV	FC-3850	Compute lunar gravitation acceleration	Sh. 15
QUICTRIG	FC-3320	Compute sines and cosines	Sh. 17
NBSM	FC-3320	Transform vector from NB to SM coordinates	Sh. 17
PRIOCHNG	FC-3030	Change job priority	Sh. 22
TRG*SMNB	FC-3320	Transform vector from SM to NB coordinates	Sh. 23
SMNB	FC-3320	Transform vector from SM to NB coordinates	Sh. 24

FLAGS

Name	Meaning When Set	Meaning When Cleared	Where Set	Where Cleared	Where Tested
LRINH FLAG 11 BIT 8	LR updates permitted by astronaut	LR updates inhibited by astronaut	Sh. 2	Sh. 3, 4	Sh. 14, 19
NOR29FLG FLAG 3 BIT 11	R29 not allowed	R29 allowed			Sh. 6
R77FLAG FLAG 5 BIT 11	R77 is on	R is not on			Sh. 6
V37FLAG FLAG 7 BIT 6	Averageg (SERVICER) running	Averageg (SERVICER) off			Sh. 6
LRBYPASS FLAG 11 BIT 15	Bypass all landing radar updates	Do not bypass landing radar updates			Sh. 6, 9
TRACKFLG FLAG 1 BIT 5	Tracking allowed	Tracking not allowed			Sh. 6
LRPOSFLG FLAG 12 BIT 6	Landing radar position 2	Landing radar position 1			Sh. 7
XORFLG FLAG 11 BIT 9	Below limit inhibit X-axis override	Above limit do not inhibit	Sh. 9		Sh. 9
XOVINFLG FLAG 13 BIT 9	X-axis override locked out	X-axis override okay	Sh. 9		
NOLRREAD FLAG 11 BIT 10	LR repositioning; bypass update	LR not repositioning	Sh. 11, 22	Sh. 25	Sh. 9, 12

MIT INSTRUMENTATION LAB
CAMBRIDGE, MASS.

DRAWN
PRGMR D. Moore 12/1/69
ANALST W. Dapkus 11/25/69
DOCMR
APPR'D R M Eyles 12/1/69

APOLLO GUIDANCE AND NAVIGATION

R12 - Descent State Vector Update

LUMINARY 1C

REV 0

DOCUMENT NO. FC-3935

FLAGS (CONTINUED)

Name	Meaning When Set	Meaning When Cleared	Where Set	Where Cleared	Where Tested
NO511FLG FLAG 11 BIT 3	Do not test LR antenna position in R12	Test LR antenna position in R12	Sh. 26		Sh. 10
PSTHIGAT FLAG 11 BIT 11	Past higate	Pre higate	Sh. 11, 22		Sh. 10, 14
RNGEDATA FLAG 11 BIT 4	LR altitude measurement made	LR altitude measurement not made		Sh. 11	Sh. 12
VELDATA FLAG 11 BIT 7	LR velocity measurement made	LR velocity measurement not made	Sh. 29	Sh. 11	Sh. 16
ALTSCALE FLAG 12 BIT 9	LR altitude reading is on high scale	LR altitude reading is on low scale			Sh. 13
HFLSHFLG FLAG 11 BIT 1	LR altitude fail lamp should be flashing	LR altitude fail lamp should not be flashing	Sh. 32	Sh. 14	
VXINH FLAG 11 BIT 12	Bypass X velocity update on next pass	Update X-axis velocity	Sh. 33	Sh. 18	Sh. 18
READVEL FLAG 11 BIT 5	Ok to read LR velocity data	Do not read LR velocity data	Sh. 21		
LPOS2FLG FLAG 11 BIT 6	Use LR position 2 transformation	Use LR position 1 transformation	Sh. 25		
VFLSHFLG FLAG 11 BIT 2	LR velocity fail lamp should be flashing	LR velocity fail lamp should not be flashing	Sh. 33		

MIT INSTRUMENTATION LAB
CAMBRIDGE, MASS.

DRAWN
PRGMR 12/1/67
ANALST
DOCMR 11/30/67
APPR'D 12/1/67

APOLLO GUIDANCE AND NAVIGATION

R12 - Descent State Vector Update

LUMINARY 1C

REV 0

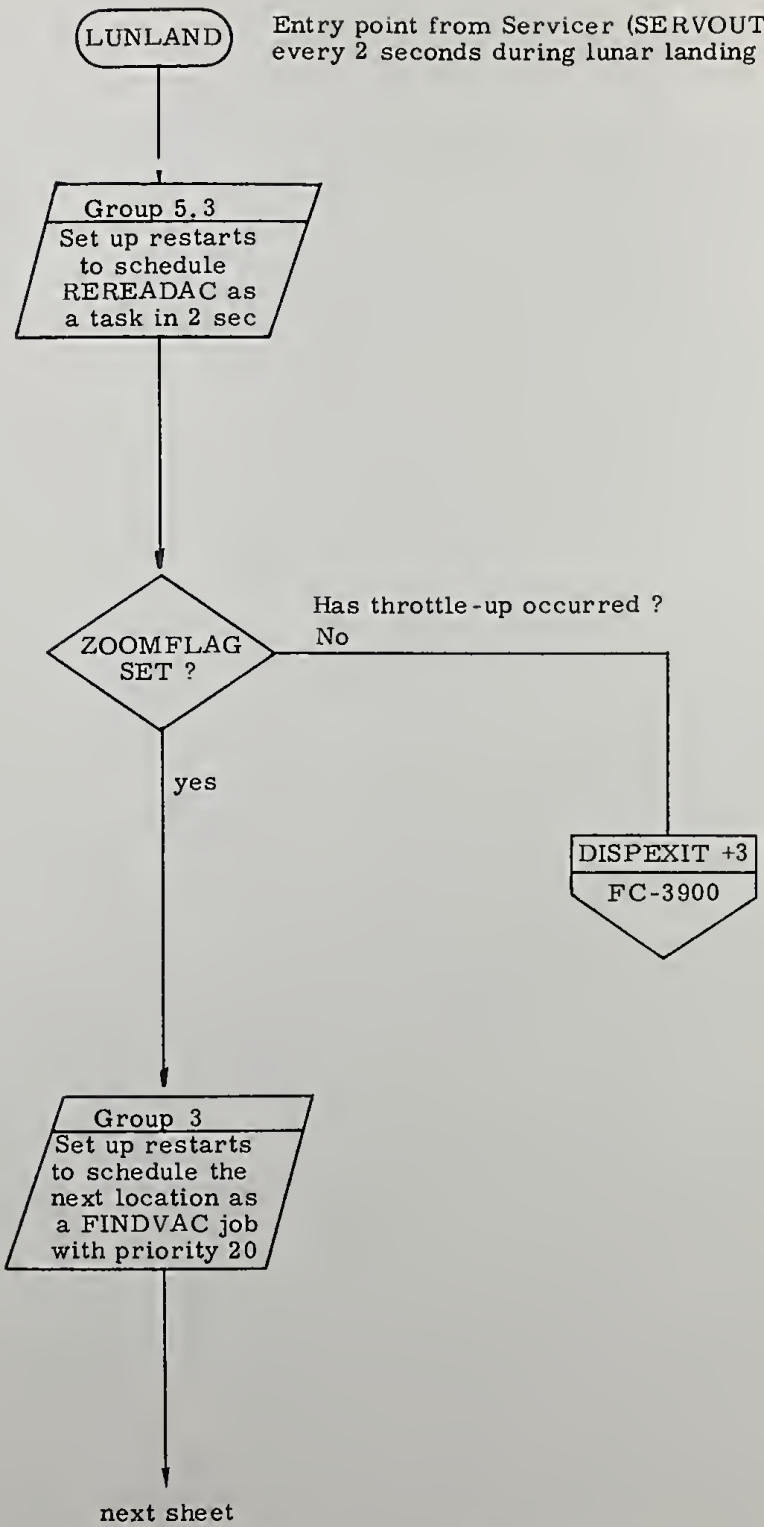
DOCUMENT NO. FC-3935

SHEET 36 OF 36

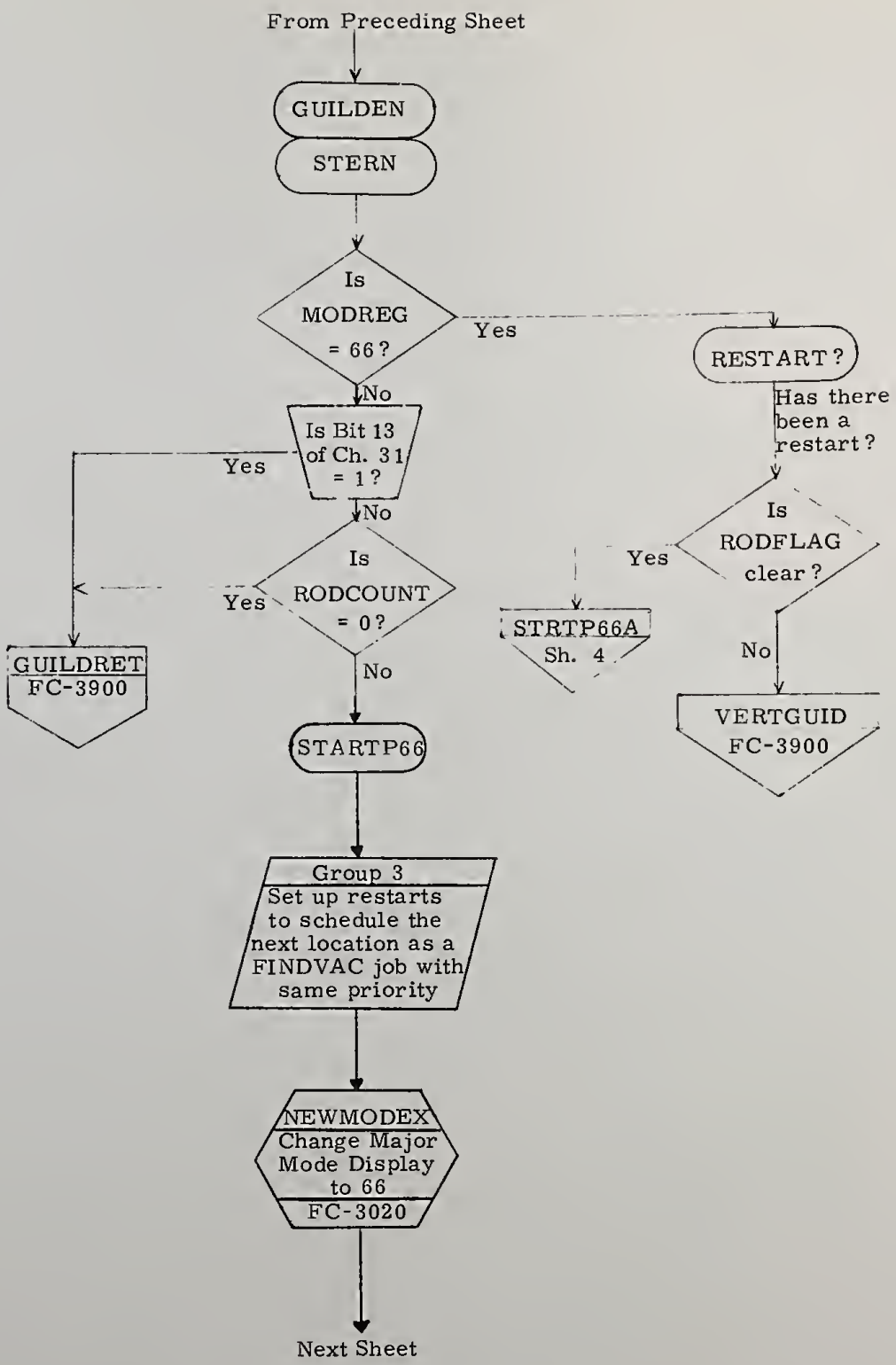
R13 - Landing Auto Modes Monitor

LUNLAND Sh. 2
DESCBITS Sh. 6

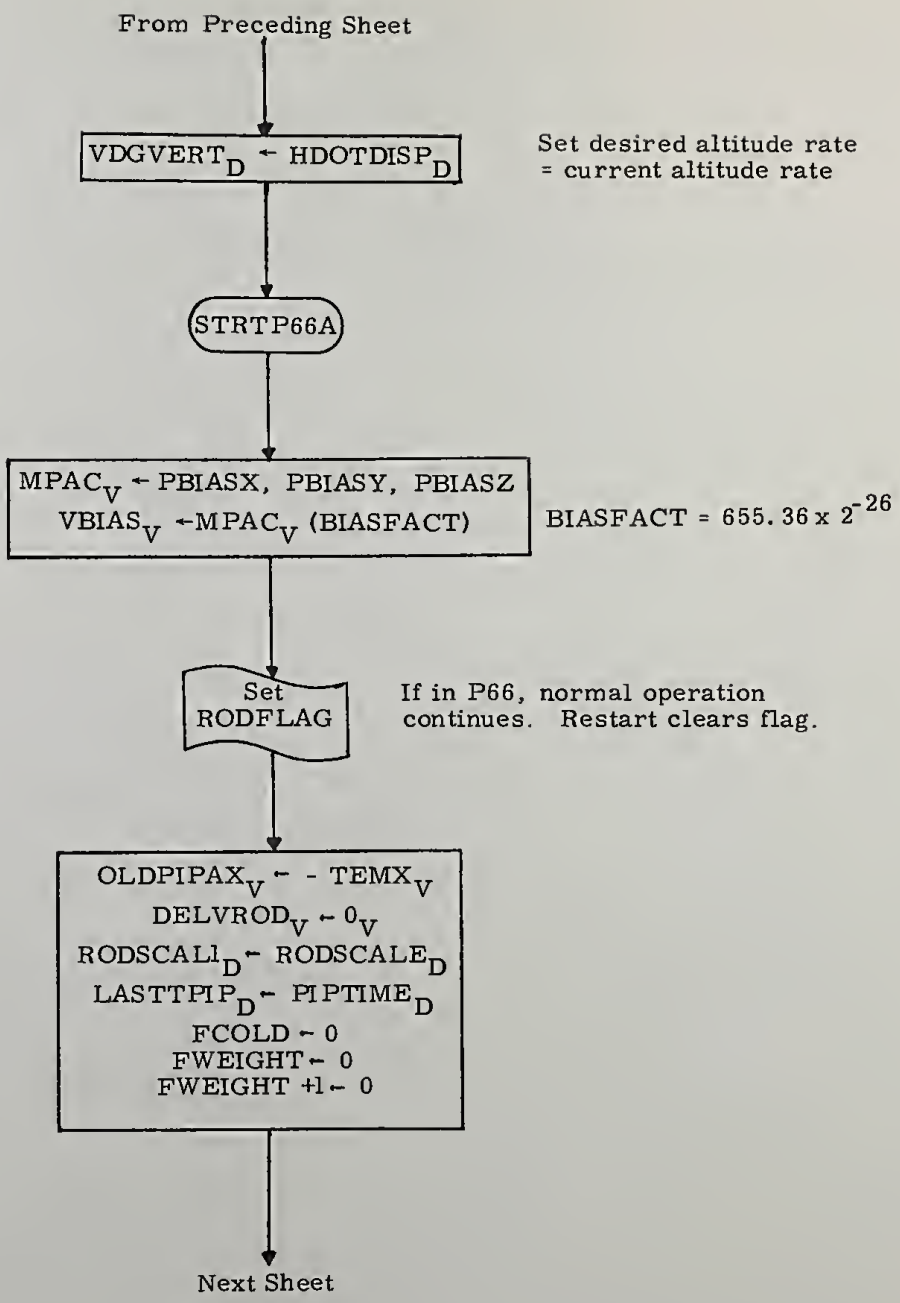
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.			APOLLO GUIDANCE AND NAVIGATION	
DRAWN	E. Walchi	12/4/69	Landing Auto Modes Monitor	
PRGMR	P. Allen	12/9/69		
ANALST				DOCUMENT NO.
DOCMR	W. Dobrott	12/5/69	LUMINARY 1C	FC-3940
APPR'D	W. Dobrott	12/16/69	REV 1	SHEET 1 OF 7



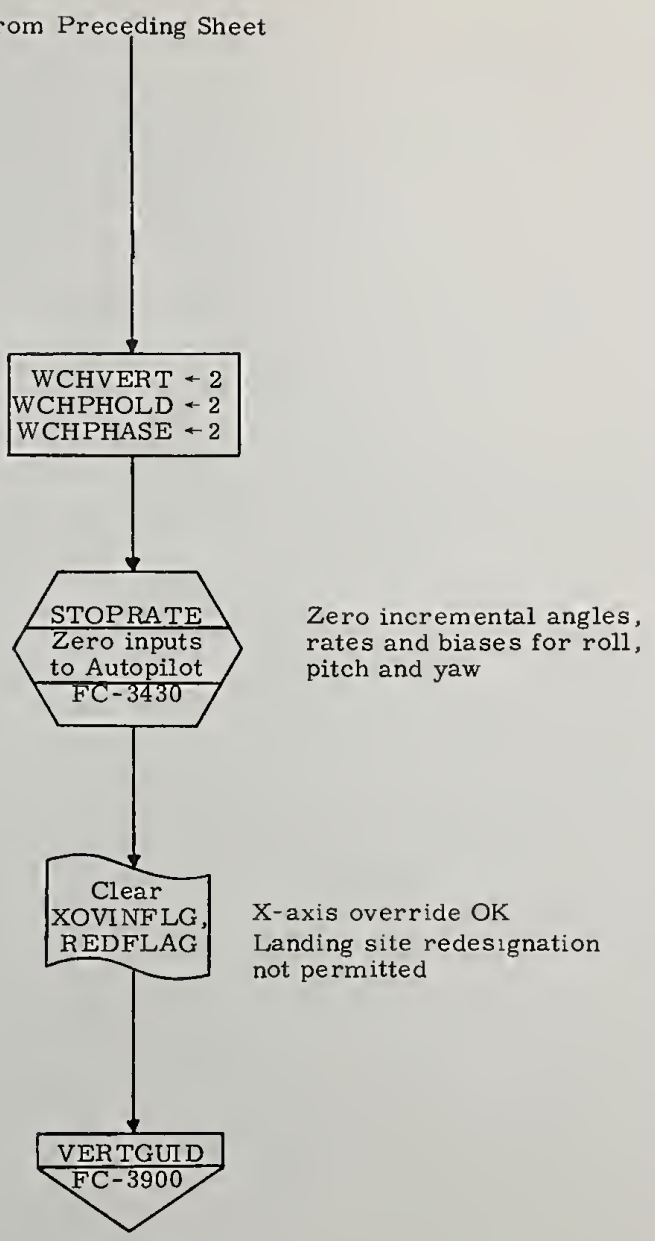
MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN D. Lutkewich	8-16-69	Landing Auto Modes Monitor	
PRGMR R. Callas	8/16/69		
ANALST			DOCUMENT NO.
DOCMR W. C. DANFORTH		LUMINARY 1C	FC-3940
APPR'D Alex M. Scott 8/16/69		REV 1	SHEET 2 OF 7



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN	12/2/69	Landing Auto Modes Monitor	
PRGMR		LUMINARY 1C	DOCUMENT NO. FC-3940
ANALST			
DOCMR		REV 1	SHEET 3 OF 7
APPR'D			

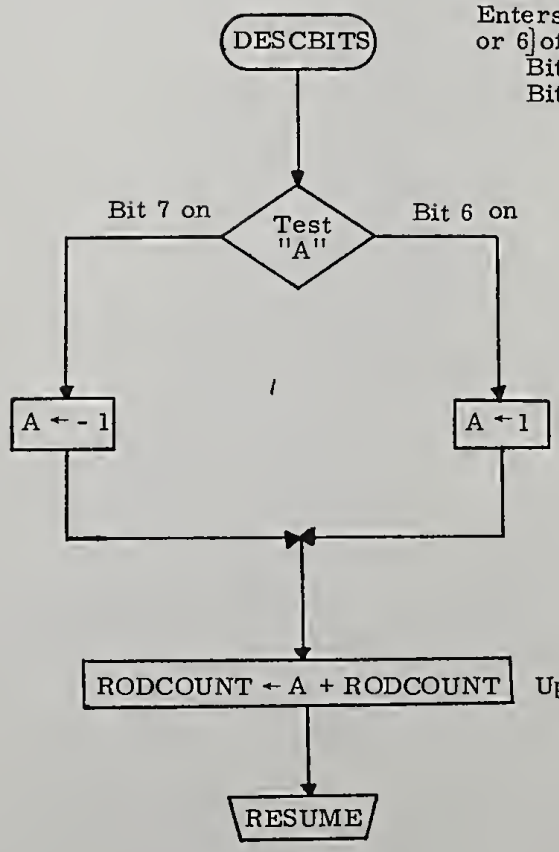


MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		Landing Auto Modes Monitor	
PRGMR	4 AUG 69	LUMINARY 1C	DOCUMENT NO. FC-3940
ANALST			
DOCMR	4 AUG 69	REV 1	SHEET 4 OF 7
APPR'D	4 AUG 69		



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		Landing Auto Modes Monitor	
PRGMR P. Adler	7 AUG 69		
ANALST		LUMINARY 1C	DOCUMENT NO. FC-3940
DOCMR W C Duggan	4 AUG 69		
APPR'D Alex Kay, Sonnabend	7 AUG 69	REV 1	SHEET 5 OF 7

Subroutine to update RODCOUNT with output from rate of descent switch activated by astronaut
Enters from MARKRUPT with [Bit 7 or 6] of Channel 16 in A.
Bit 7 = - rate increment
Bit 6 = + rate increment



MIT INSTRUMENTATION LAB CAMBRIDGE, MASS.		APOLLO GUIDANCE AND NAVIGATION	
DRAWN		Landing Auto Modes Monitor	
PRGMR	R Hobbs 20 Nov 68	LUMINARY 1C	DOCUMENT NO. FC-3940
ANALST			
DOCMR	W C Dykstra 4 Dec 68	REV 1	SHEET 6 OF 7
APPR'D	Alan M. Green 4 DEC 68		

SUBROUTINES CALLED ON OTHER FLOWCHARTS

Subroutine	Flowchart	Description	Where Called
DISPEXIT	FC-3900	Lunar Landing Entry Point	Sh. 2
GUILDRET	FC-3900	Lunar Landing Entry Point	Sh. 3
VERTGUID	FC-3900	Lunar Landing Entry Point	Sh. 3, 5
NEWMODEX	FC-3020	Change Major Mode Display	Sh. 3
STOPRATE	FC-3430	Zero Inputs To Autopilot	Sh. 5

FLAGS

Name	Meaning When Set	Meaning When Cleared	Which Set	Where Cleared	Where Tested
ZOOMFLAG Flag 5, Bit 8	Throttle-up has occured in P63	Throttle-up has not occured in P63			Sh. 2
RODFLAG Flag 1 Bit 12	If in P66, normal operation continues	If in P66 reinitialization is performed	Sh. 4		Sh. 3
XOVINFLG Flag 13 Bit 9	X-axis override locked out	X-axis override permitted		Sh. 5	
REDFLAG Flag 6 Bit 6	Landing site redesignation permitted	Landing site redesignation not permitted		Sh. 5	